[UNIVERSITY OF LONDON]

# WYE COLLEGE

## Department of Hop Research

# ANNUAL REPORT

## 1957

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# DEPARTMENT OF HOP RESEARCH

## Introduction

Since the last report of the Department was written, tests have been carried out which have shown that the single case of *Verticillium* wilt recorded in a College hop garden in 1956 was of the non-serious or fluctuating type. No case of the dangerous Progressive Wilt has therefore been recorded on the College farm since 1955. There are now good grounds for hoping that the outbreak of this most serious disease has been contained and suppressed and that the College will avoid the necessity of having to accept the difficult status of a "wilt farm" in East Kent.

This major improvement in the wilt position has removed much of the atmosphere of suspense and uncertainty which has enveloped the Department for more than two years and has adversely affected its research work. Firm plans are being drawn up for future research and the College has made available another field to replace the garden which was grubbed on account of Progressive Wilt. The establishment of this new garden is now in progress. It is hoped that in a few years, provided no further cases of wilt are recorded, the College may be declared officially to be an uninfected area. Until then it is regretted that the present embargo on visitors to the hop gardens must continue.

During 1957 hop research at Wye has continued to develop. In addition to progress along well-established lines in plant breeding, plant nutrition and organic chemistry, new aspects of hop research have received attention. Investigations on crop physiology were begun in 1957 and are already yielding results. Research on Downy Mildew disease which was started in 1955, has progressed satisfactorily. Acknowledgment is due to Dr. Dorothy Derbyshire who has done much in her short time in the Department to define and place in perspective the problems connected with this costly disease and to indicate lines of approach for future work. Dr. Derbyshire resigned her post in March, 1958; she will be succeeded by Mr. Coley-Smith.

The College expresses its gratitude to the Agricultural Research Council, the Hops Marketing Board and the Institute of Brewing for their support to the Department. The resoluteness of this support

during the critical and costly years of the wilt outbreak has given great encouragement to the Governing Body of the College and the staff of the Department, and merits the thanks of all those who are interested in the well-being of hop research at Wye.

DUNSTAN SKILBECK.

June, 1958.

# REVIEW OF RESEARCH

H. S. Darling

As in previous years, this report of the Department of Hop Research is concerned primarily with the discussion of current departmental work. It also contains a number of appendices, including some written by workers in other organizations, in which topics relevant to hop research at Wye are considered.

The activities of the Department have been greatly facilitated by the improvement in the wilt position on the College Farm which is referred to in the introduction to this report on page 5 and is discussed in detail in an article on page 13. This improvement has permitted a more assured approach to the planning of future work. As mentioned on page 16 a new hop garden is being planted, the establishment of which will take place in stages during 1958-60.

The growing demand in Britain for hops for lager brewing is noted in Appendix III, where the possibility is discussed of breeding English varieties suitable for this specialized type of beer. The insistence by lager brewers on seedless hops is stressed; it would appear that the polyploid breeding techniques now in use at Wye may provide an answer to the otherwise insoluble problem of how to grow hops of minimal seed content under English conditions of heavy pollination.

Some of the results of current research at Wye on triploid hops are given in two papers on pages 43 and 50 of this report. The latter paper deals with the seed content of these hops and confirms earlier work, showing that while triploid cones contain many fewer seeds than normal diploid cones, they are not seedless in the strict sense of the word. It remains to be seen if their seed content is sufficiently reduced to satisfy those brewers who demand a seedless hop. The former paper discusses resin inheritance in triploid hops. Data obtained from whole families, rather than from selected seedlings, suggest that the characters concerned are controlled by the cumulative effect of many genes. The data also indicate that triploid cones have significantly more resin than those of the diploid parent, and that this difference may be accounted for by the lack of seeds in the triploids.

The use of polyploidy in current work at Wye is indicated in the review of plant breeding research on page 17. These investigations are directed mainly towards the production of wilt-tolerant varieties of accepted English quality. Triploid seedlings of Fuggle and Golding hops pollinated by wilt-tolerant males have been raised and small samples of cones have been assessed by the Trade for quality on the basis of physical examination. Several years of testing still await the more promising of these triploid seedlings but the preliminary results of this work are distinctly encouraging. Meanwhile, four English-type, diploid wilt-tolerant seedlings, produced by conventional techniques in the Wye/East Malling Joint Scheme, have been selected for propagation at Wye for farm trials to be planted in the winter of 1959-60.

In order to complete the containment and suppression of the Progressive Wilt outbreak recorded in the western half of Wye Field Garden in 1954-55, the hops in the apparently wilt-free eastern half of this garden were grubbed as described on page 13. This brings to an end the history of the Wye Field variety trial plots in which many of Professor Salmon's new seedling varieties have been tested. Summarized data on 42 of these seedlings are presented in an article on page 60. Material of the more important of these seedlings is at present in quarantine in the Cambridge area.

As mentioned on page 14, the departmental quarantine gardens near Cambridge have made satisfactory progress and the main plant breeding collection has safely completed two years of growth in isolation. The freedom of this collection from Progressive Wilt has been confirmed by staff of the National Agricultural Advisory Service who inspected the plants in growth in 1956 and 1957 and made detailed laboratory examination of representative samples of rootstock material. In March, 1958, setts from this collection were planted on what is to be its permanent site at Luddington Experimental Horticulture Station, near Stratford-on-Avon.

Included in this collection are 34 clonal selections from commercial stocks of Fuggles, Goldings and Golding Varieties. It is hoped that in due course Luddington material will be used to establish variety trials in the West Midlands to determine which of these promising selections are best suited to local conditions. Meanwhile, as described in the review of the work on field experimentation and plant nutrition on page 22, testing of these clones is continuing at Wye. The 23 clones of Goldings and Golding Varieties have been planted in a replicated trial, and yield data will be recorded for the first time in 1958. The 11 Fuggle clones are to be

planted in a replicated trial in the new Withersdane Garden (which replaces Wye Field) in the winter of 1958-59.

The review on page 23 also discusses manurial trials of factorial design which are in process of establishment in the South-Eastern Region at Bodiam in Sussex and at Teynham in Kent on the land of Guinness Hop Farms Ltd. These trials, involving three levels each of N, P and K, should begin to yield results in 1958 and should go far to meet a long-felt need. They are to be augmented by a similar trial to be planted in the new Withersdane Garden at Wye in the winter of 1958-59.

Withersdane Garden is also to contain a new height of wirework and spacing trial with Bullion, Fuggle N and Northern Brewer. These varieties were planted out in position in the spring of 1958 and the wirework is to be erected over them in the winter of 1958-59. It is hoped to record data from 1960 onwards.

The results of the earlier Wye Field trial on height of wirework and spacing (which was grubbed in 1955 because of Progressive Wilt) are embodied in an article on page 82. Data obtained during 1953-55 indicate that the use of higher wirework may increase yield per acre and give bine growth which is more suited to machine picking.

Preliminary investigations were made in 1957 on the relationship between weight of spray deposit on leaves and the volume of spray fluid applied per acre. An air-assisted technique was used and standard weights of copper formulations were applied per acre in 50, 100 and 150 gallons of water. The deposit was found to vary very widely from leaf to leaf on the same plant and from place to place on the same leaf. The results obtained showed a trend indicating that the weight of deposit per unit area of leaf decreased with decrease in the volume of spray applied. Infection by Downy Mildew was not severe in 1957 and field observations suggested that under these conditions the lighter low-volume deposit gave as effective disease control as the heavier cover obtained with high volume treatments.

Research on Downy Mildew is reviewed on page 35. Investigations into the bionomics of the fungus have continued and time has been devoted to developing techniques for assessing the susceptibility of varieties to the disease. A method using very young seedlings at the four-leaf stage shows promise. If confirmed this may accelerate plant breeding research by enabling new material to be tested at an early age. It is hoped eventually to breed resistance to Downy Mildew into wilt-tolerant varieties of standard English quality.

Results of four years of testing with captan suggest that

this relatively expensive organic sulphur fungicide is as effective as Bordeaux mixture in controlling Downy Mildew and may give slightly increased yields of dried hops per acre. Owing, however, to the risk of causing tainting in beer it should not be applied after mid-August.

The work of the organic chemist is discussed on page 27. Small-scale exploratory experiments on the importance of light, leaf area, and sugar content as factors in the synthesis of hop resins in the cones have given inconclusive results. This work has shown, however, that under normal English climatic conditions there appears to be no direct relationship between the content of reducing sugars in the hop cone and the content of alpha resin. The enzyme, peroxidase, may well be of importance in the synthesis of hop resins. In an article on page 92 an improved technique is described for determining the peroxidase content of hop leaves and cones.

In addition to the investigations mentioned above, the importance of the work of the organic chemistry section is indicated by the large number of routine analyses carried out in support of other departmental research. In view of current advances in hop chemistry at the Brewing Industry Research Foundation, this importance may be expected to increase in future.

Work on systemic insecticides is reviewed on pages 33 and 98. Studies on the concentration of dimefox in hop plants, made in collaboration with the Government Chemist, showed that the normal soil application of 0·5 gm. active ingredient per plant on May 31st maintained levels of 1 p.p.m. (green weight basis) until the end of July. This appeared to give satisfactory aphis control. Concentrations in the plant fell rapidly in August. This fall was not prevented by a further half-strength application on July 19th which caused only a temporary increase in dimefox in the plants and which did not result in dangerous residues in the cones. Farm data have been collected in East Kent which suggest strongly that the introduction of systemic organo-phosphorus insecticides into commercial use in hops from 1949 onwards has been followed by an increase in the ratio of bushels of green hops per cwt. of dried hops.

A crop physiologist was appointed to the Department for the first time in July, 1957. The field of work to be covered by this appointment is discussed in Appendix IV and progress already made is reviewed briefly on page 41. Growth studies, while inevitably of a long-term nature, are fundamental to the proper interpretation of the results of other lines of hop research, and data from this new work should prove of great value. Studies on plant dormancy and the

associated build-up of food reserves in the rootstock may provide data which will help in reducing the adverse effects of machine picking on yield. Germination of hop seeds can be uncertain and this may be a hindrance to plant breeding and pathological research. Investigations on the breaking of seed dormancy, carried out at Wye in the winter of 1957-58, are discussed in an article on page 108 in which the importance of low temperature treatment of presoaked seed is indicated. The irrigation of hops has not yet been investigated under English conditions. This subject is reviewed in Appendix V where it is mentioned that experiments are to be carried out on the Guinness Hop Farms this summer. It is hoped that the results from these trials will be given in the departmental report for 1958.

The National Institute of Agricultural Engineering continues to collaborate with Wye in research on hop drying. In Appendix VIII a summary account is given of a paper by the N.I.A.E. of the performance of a conventional, batch-operated kiln of modern design. This work establishes standards by which to assess the working of continuous drying machines now reaching the Industry. Further papers by the N.I.A.E., which are now in the press, discuss the performance of such continuous driers; they also describe research in 1957 in which the small experimental kilns at Wye were used to investigate factors likely to be of importance in continuous driers of advanced design.

Acknowledgment is made to the Ministry of Agriculture, Fisheries and Food for permission to publish Appendices VI and VII, contributed by Mr. Chater and Miss Jary of the National Agricultural Advisory Service, in which the 1957 hop season is described from the growers' point of view. Among the points of importance which are raised, it will be noted with concern that Progressive Wilt has been recorded for the first time in the West Midlands where it has threatened the valuable hop experiments at Rosemaund Experimental Husbandry Farm. It will also be noted that the number of picking machines in England has increased still further. It is probable that in 1957 more than 40 per cent. of the total acreage was so harvested. Too many samples of machine-picked hops contained an unduly large proportion of leaf and stem and commercial valuations have reacted consistently against this undesirable trend.

In Appendix II, Mr. Pocock of Nottingham University discusses the results of his survey of changes in hop acreage in south-eastern England during the past 100 years. His findings indicate that while fluctuations have been violent, they have not affected the over-all

balance and distribution of the Industry; the relative importance of different areas, involving a wide range of soil types, has remained largely unaltered.

Hop research outside Wye is reviewed in Appendix VIII which, in addition to listing papers published by departmental staff, contains notes and abstracts relating to work at other research centres in England and in countries overseas. In the latter, hop research is expanding, notably in central Europe and in New Zealand and Australia. The Department has been enabled to keep in close touch with European work on hops by participation in the activities of the Scientific Commission of the European Hops Cultural Committee. A session of this commission, at which Wye was represented, was held in France at Dijon and Strasbourg in July, 1957. Papers on hop research were presented by delegates from Belgium, Britain, Czechoslovakia, France and Yugoslavia.

In addition to its research work at Wye, the Department has kept in touch with the Industry and its problems through the Hops Marketing Board, the National Agricultural Advisory Service, the Institute of Brewing and the Association of Growers of the New Varieties of Hops. During the year members of the Department have attended meetings of appropriate committees of these bodies, including the Hops Working Party; they have also given lectures on their work at meetings of growers and brewers, and have helped in the "Barley Mow" exhibit staged by the Institute of Brewing at the Royal Agricultural Show.

Thanks are due to East Malling Research Station, to the National Institute of Agricultural Engineering, to the Department of the Government Chemist, and to the Brewing Industry Research Foundation, for their co-operation in problems of common interest. Grateful acknowledgment is made of help received from many growers and from members of the Trade including Wild, Neame & Gaskains Ltd., Wigan Richardson & Co., and Wolton, Biddell & Co.

Thanks are due to the National Agricultural Advisory Service and the National Institute of Agricultural Botany for help in the establishment and maintenance of departmental outstations in the Cambridge area and at Luddington near Stratford-on-Avon. The Department is also deeply indebted to Dr. H. H. Glasscock, Advisory Plant Pathologist, N.A.A.S., Wye, for help in problems arising from the wilt outbreak on the College farm and for advice on research on Hop Downy Mildew.

# PROGRESSIVE WILT AT WYE COLLEGE AND QUARANTINE GARDENS

H. S. Darling

In his introduction to the Annual Report of the Department for 1956, Principal Skilbeck gave warning that any further deterioration in the wilt position in the College hop gardens in 1957 might have far-reaching effects on hop research at Wye College. It is now clear that no such deterioration has taken place but that instead there has been a considerable improvement.

No further cases of *Verticillium albo-atrum* were recorded in the College hop gardens in 1957. Pathogenicity tests were carried out by the National Agricultural Advisory Service and by East Malling Research Station with the fungus isolated from the single wilt-infected hill found in the Nursery Garden in September, 1956. These tests have shown that this 1956 infection was Fluctuating Wilt, being the first recorded incidence of this strain of the fungus at Wye College.

No case of Progressive Wilt has been recorded at Wye since 1955 and it appears probable that the outbreak on the College farm has been suppressed. The hops in the eastern half of Wye Field Garden were grubbed and burned and the wirework dismantled in November and December, 1957; the area so cleared is to be sown down to permanent grass in 1958. As previously reported, the western half of Wye Field, in which the outbreak of Progressive Wilt occurred, was cleared of hops in late 1955 and sown down to permanent grass in 1956.

Fluctuating Wilt has no legal significance and is of little direct economic importance. Owing to its resemblance to Progressive Wilt, however, its incidence at Wye College is a matter of some concern. At the present critical stage in the suppression of the 1954 outbreak of Progressive Wilt, any occurrence of Fluctuating Wilt in the College hop gardens will temporarily confuse the situation; pending the carrying out of a pathogenicity test it will intensify the atmosphere of uncertainty which has already proved so inimical to the planning and development of the Department's research programme.

Full steps have therefore been taken under the guidance of the N.A.A.S. to suppress the 1956 outbreak of Fluctuating Wilt

which occurred at the eastern end of the Nursery Garden. The single hill involved was grubbed and burned as were its 15 immediate neighbours in September, 1956. The site was treated with formalin and covered with sacking and wire netting to prevent any movement of infected soil. With the same object in view the cultivation of the surrounding area was stopped and it was allowed to "tumble down" to a natural sward. Advantage is being taken of current changes in the Department's hop gardens to arrange for the hops in this area to be grubbed in the coming winter and for this end of the garden to be transferred to the Horticultural Department in exchange for clean land adjoining the Nursery Garden.

The Department's quarantine gardens in the Cambridge area have been maintained. The two gardens at Boxworth have made good growth; the establishment of the Lolworth garden, which was planted in March, 1957, has been satisfactory. All three gardens were inspected in the late summer by N.A.A.S. staff who found them free from symptoms of *V. albo-atrum*.

In March, 1958, planting material for the main plant breeding collection was moved from quarantine at Boxworth to Luddington Experimental Horticulture Station near Stratford-on-Avon. There it was planted on a permanent site on which wirework was erected by departmental staff in November, 1957. The setts for this transfer were lifted in November, 1957, and samples taken for laboratory examination. The setts were subsequently bedded-in temporarily at Boxworth in clean soil until removed to Luddington in March, 1958. Examination of the samples by the N.A.A.S. pathologist at Wye in December, 1957, failed to reveal any infection by *V. albo-atrum*.

# REVIEW OF THE 1957 HOP SEASON AT WYE COLLEGE

H. S. Darling

In 1957 a mild winter was followed by a dry sunny spring; this sequence of seasons resulted in poor soil conditions which made it difficult to achieve a good tilth. Established plants made good growth but young plants were adversely affected. From July onwards the summer was wet and stormy with low figures for sunshine. Such conditions were not favourable for the production of a vintage crop and the resulting harvest was no more than average in respect of size and quality. Meteorological data for Wye for April-September, 1957, are tabulated below; mean data for 1935-56 are given for comparison.

| | Rainfall Inches per month | | Sunshine Hours per day | | Mean Temperature °F. | |
|---|---|---|---|---|---|---|
| | 1957 | 1935–56 | 1957 | 1935–56 | 1957 | 1935–56 |
| April .. | 0·49 | 1·60 | 6·1 | 5·9 | 48·3 | 47·6 |
| May .. | 1·52 | 1·97 | 7·3 | 7·0 | 50·9 | 53·0 |
| June .. | 0·96 | 1·73 | 9·8 | 7·4 | 59·8 | 58·6 |
| July .. | 3·31 | 2·20 | 5·7 | 6·8 | 63·3 | 61·8 |
| August .. | 4·01 | 2·53 | 6·0 | 6·4 | 60·8 | 61·8 |
| September .. | 3·67 | 2·31 | 3·9 | 5·1 | 56·3 | 58·0 |

The incidence of Downy Mildew disease was maintained at a low level throughout the season, copper sprays being applied on seven occasions. Mould disease was controlled by repeated applications of sulphur. Attack by the Hop Aphis began in mid-May and was controlled by systemic insecticides. The Potato Aphis (*Macrosiphum euphorbiae*) was common on young shoots in the spring but disappeared in the summer. No attack by the Hop Red Spider was observed.

The crop was harvested in 21 picking days during the period September 5th to October 1st. The number of hand pickers available was much less than in previous years and a further decline must be expected in 1958. The crop weighed poorly on drying, giving

an average ratio of 125 bushels per dried cwt. Yields per acre, while much higher than in 1956, were not above average. Established Goldings gave about 21 cwt. dried hops per acre and yields from mature hills in the plant breeding plots were of the same order. The total yield as weighed at the College oast after drying was 147 cwt. compared with 67 cwt. harvested from the same acreage in 1956. Of the 1957 total 53 cwt. were Goldings; the rest were unnamed hops from plant breeding rows and plots.

The crop valued well. All the Golding hops received Grade I prices plus maximum bonus.

The eastern four acres in Wye Field, consisting mainly of trial plots of unnamed seedlings, were picked for the last time in 1957. This area has now been grubbed and is being sown down to permanent grass.

Preparations are well advanced for the planting of a new hop garden in Withersdane Field to replace the Wye Field Garden which has been lost to hops on account of Progressive Wilt. This new garden is to include a height of wirework and spacing trial, a manurial trial, plant breeding variety trial plots and other experimental hops. Planting and erection of wirework will be carried out by departmental staff in stages during 1958-1960. The eastern boundary of Withersdane Field lies on a right of way; a new fence has been erected on an alignment which ensures that this right of way is outside the hop garden.

# PLANT BREEDING SECTION

## REVIEW OF THE YEAR'S WORK

R. A. Neve and R. F. Farrar

### General

These reviews have, for the past three years, referred to the work of reorganization which was carried out to enable more precise plant breeding methods to be operated. It is gratifying this year to be able to record below, in the case of the triploid seedlings of Fuggle, the first benefits which have resulted from the new system. These seedlings, which cropped for the first time in 1957, were the result of pollinations made in 1955, but the successful results obtained depended upon the reorganization begun in 1953, and the programme of research into polyploidy initiated by Dr. Dark in 1950. Such time lags are an inevitable feature of plant breeding activities, but with much of the preliminary work completed there should be a steady flow of results in the years ahead.

The improved situation in respect of *Verticillium* wilt means that the breeding programme should go ahead as planned without interruption. The primary aim of this programme is the production of wilt-tolerant seedlings and there is no doubt that the process of selection could be speeded up if a departmental station was available for wilt testing large numbers of seedlings at an early stage. Such a station was planned in the event of wilt becoming established at Wye. This plan has been withdrawn in view of the improved wilt situation, and it must be admitted that, with the present staff, the running of such a station would present great difficulties at a time when the section is already heavily engaged on outstation work. It is estimated that in 1957 the outstations occupied nearly one-sixth of the working time of both senior members of the section. These activities should decrease from now on, and as they do so the desirability of increased wilt testing facilities should be borne in mind. In the meantime experiments are being carried on, in conjunction with East Malling Research Station, to determine the most satisfactory method of testing seedlings as early as possible.

The work on outstations during the year included, in addition to general maintenance, the planting of the garden at Lolworth,

erection of wirework at Luddington, and lifting and bedding-in of planting material to be transferred from Boxworth to Luddington.

The development and testing of any new seedling involves a considerable amount of propagation, and in most seasons this is part of the normal routine. The unusual weather conditions in the early part of 1957, however, seriously affected the establishment and subsequent growth of propagation material. The mild weather in January and February which caused cuttings to shoot in the bedding-in ground, was followed by a long cold dry period in March after the material had been planted out in the nursery rows. These conditions resulted in the loss of a large proportion of the propagation material. In some clones it was possible to make good the losses by striking laterals later in the season. This technique requires glasshouse and frame space, and involves a considerable amount of care and attention at a time of the year when other work is pressing; for this reason it was only applied to those varieties of immediate importance. The fact that some clones, due for investigation, were not built up during the season, means that they will have to be carried on through the propagation process for at least one extra season; this in turn means a certain amount of delay in the programme for those varieties affected.

### Verticillium Wilt Tolerance

*Wye/E.M.R.S. Joint Scheme*

The selection of varieties for farm trials was the most important aspect of the programme during 1957. Of the 40 varieties remaining in the scheme, enough information had been gathered on 14 for them to be considered, and the propagation layout was designed to concentrate on them. The need for some 1,200 plants of each variety selected for farm trials to be available for planting in the winter of 1959, meant that the build up had to begin during 1957.

As in previous years, dried samples were sent to merchants for commercial assessment, and to the Brewing Industry Research Foundation for small-scale brewing trials. Samples were picked only from the varieties being considered for farm trials.

The results of small scale brewing trials that have been carried out on selections from the scheme, appeared to be most encouraging. The general impression was that all the samples provided could be used in brewing, with no detrimental effect on the resultant beers; in fact in some cases, tasters expressed a preference for the beer in which a Joint-Scheme variety was used, over that brewed with a

Fuggle control. As was the case with the 30-plant wilt tolerance tests, so many varieties came through, that final selection has had to be based largely on field performance and the opinions of the merchants.

Four varieties have been selected for farm trials, and these will be propagated during 1958 and 1959 to provide all necessary planting material. A further four varieties with higher resin contents than Fuggle, have been noted as showing possibilities, but as far as the scheme is concerned, they are not eligible for consideration because their aromas are of the American type. Nevertheless a tolerant variety of this kind, even with an American aroma, may be of value, and it is hoped to investigate further these four varieties.

Now that a choice has been made for farm trials, the remaining material in the scheme is not being abandoned; there are still a number of varieties which have not been subjected to all the preliminary tests, and these will be sorted out during the next few seasons. If necessary, a second series for field trials will be selected.

The nine varieties submitted to wilt test at East Malling during 1957, all proved tolerant, but six other varieties were removed from the scheme because of poor field performance or lack of quality. This leaves a total of 34 varieties remaining in the scheme.

*Tetraploid Fuggle N × wilt tolerant males*

The triploid seedlings from these six crosses made excellent growth at the start of the season, but then appeared to be checked by the dry spring rather more seriously than were the older plants in the garden. However, growth was good enough for full records to be taken and samples picked for various purposes. The overall picture of these seedling families was that they showed considerably more uniformity than would have been expected from diploid families. In general the seedlings were later maturing than the Fuggle controls and there was a good deal of "wither cone", but the Fuggle plants also suffered from this trouble to some extent.

There were very noticeable differences between certain of the families, and in this respect the trial proved a satisfactory progeny test of four of the male parents involved, but the other two families were too small to give a reliable picture. Small samples were picked from up to fifty plants in each family for resin analysis, while the whole crop was picked from the most promising plants and box samples were sent to two merchants in the Borough for their opinions. The results of the resin determinations, which are described in detail elsewhere in this report, show generally higher resin contents in the seedlings than in the Fuggle controls, which

can mostly be attributed to the lack of seed in the triploids. Significant differences of resin content also occurred between families and indicate the value of the male parents in this respect. The general conclusions about the six families, on the results of their first cropping season are as follows:

4x Fuggle × II61. The largest family (277 seedlings) and the highest resin content, but no seedlings were considered promising.

4x Fuggle × OB79. Another family with high resin content. Of 49 seedlings, two were sent to the Borough and both had American aromas—one considered good and the other doubtful.

4x Fuggle × ♂15. A high proportion of the seedlings had cones of the Fuggle type. Resin content was lower than the first two families. Of 102 seedlings six were thought promising, and, of these, three received favourable and three unfavourable reports from the Borough.

4x Fuggle × OL45. Similar to the seedlings of ♂15 in resin content. Of 74 seedlings, three were sent to the Borough and all were liked.

4x Fuggle × 321. Resin content as for ♂15 and OL45 families. Two seedlings out of 31 were sent to the Borough; neither was liked.

4x Fuggle × 211. The smallest family with only 18 seedlings. Two were sent to the Borough and neither was liked.

The II61 family was disappointing in the field, but from the other families 5 per cent. of the seedlings were considered good enough to justify sending samples to the Borough, and half of these samples received favourable reports, a result which is considered highly satisfactory.

*Diploid and tetraploid Eastwell Golding × wilt tolerant males*
*Diploid Fuggle N × wilt tolerant males*

These families were raised and planted out satisfactorily, and most plants flowered in their first season.

*New Crosses*

The following crosses involving wilt tolerant males were made successfully:

Diploid and tetraploid Eastwell Golding × OB79.
Tetraploid Early Bird × OB79 and 321.
Diploid Fuggle × 15, OR80 and 321.

### Downy Mildew Resistance

The inoculation of young seedlings to test their resistance promises well and will probably become the standard method of selection in the first instance.

A cross was made between a Downy Mildew resistant female (7k 491) and wilt tolerant male (OB79).

### Polyploidy

Colchicine treatment was carried out on three clones of Hallertau and met with some success.

A tetraploid form of ♂ 169 has now been isolated, and this and the diploid form were both used to pollinate diploid Fuggle N.

Investigations into the seed content of triploid varieties were continued, and the method of analysis used at Wye was compared with that used commercially in America. The American method appears to be the only technique used for seed content determination in the hop trade, and the results of comparable samples analysed by the two methods differed slightly, the Wye method giving higher figures for seed in most cases. The reasons for this and an account of the work are published elsewhere in this report.

### Pollination Methods

Cellophane bags were again used in the glasshouse to enclose the female flowers and four controls showed that no contamination occurs when this method is used.

There are strong indications that artificial pollination is having a marked effect on the sex ratio in resulting families, and in certain cases this is seriously affecting the breeding programme. Further investigations are being made and it is hoped, as a result, to devise methods whereby a high or low proportion of male seedlings can be obtained as required to suit each breeding project.

# FIELD EXPERIMENTATION AND PLANT NUTRITION SECTION

## REVIEW OF THE YEAR'S WORK

F. C. Thompson, F. H. Beard and E. G. Cripps

### General

The section has continued to assist the Head of the Department in the general management of the commercially grown hops at Wye. An account of the growth of the crop, from this aspect, is given on page 15.

Talks given have included ones on hop production and hop manuring by Mr. Thompson (Conference of Lecturers in Agricultural Engineering, at Wye College; Conference of N.A.A.S. Officers at Wye) and on hop farming by Mr. Beard (Young Farmers' Club Meeting). Mr. Beard also demonstrated at the "Barley Mow" exhibit organized by the Institute of Brewing, at the Royal Show, Norwich.

Mr. Thompson continued to serve as a member of the Hops Working Party of the N.A.A.S., and of the Scientific Commission of the European Hops Culture Committee. He read a paper on "The Influence of Manuring and Other Cultural Factors, on the Resins Content of Hop Cones" at the Conference of the Scientific Commission held in Dijon, France, in July 1957.

Papers published by members of the section are referred to on page 152.

### Height of Wirework and Spacing Trial

With the recent acquisition, for hop experiments, of Withersdane Field on the College farm, preparatory work has been carried out for the establishment of a new trial to replace the one lost through an outbreak of progressive *Verticillium* wilt in Wye Field garden.

In the new trial the treatments will comprise three heights of wire-work, 14 ft., 16 ft. and 18 ft., combined with three spacings in one direction of $6\frac{1}{2}$ ft., $7\frac{1}{2}$ ft. and 9 ft. The cross spacing will be uniform at $6\frac{1}{2}$ ft., to facilitate cross cultivation. The treatments will be tested on three varieties—Fuggle "N", Northern Brewer and Bullion. Records will be taken of crop yield and determinations made of the

resins content of cones and, in addition, the experiment will be used by the crop physiology section to study, by growth analysis methods, the effect of the different treatments on the pattern of growth made by the three contrasting varieties of hops tested.

### Wye Field Variety Plots

Final records were taken of plant growth and disease incidence in these plots, prior to grubbing in the autumn of 1957. The crops from 52 varieties were picked and dried separately, giving information on yield and bushel/cwt. ratio and providing material for market valuation and brewing trials. Results are summarized in the accompanying table; a fuller report on 42 of the varieties is given on page 60.

### The Testing and Selection of Fuggle and Golding Clones

A new randomized trial of selected Golding clones was successfully established in Silks Garden. Planting material of clonal Fuggle selections was maintained for eventual establishment in large-scale plot trials in the new Withersdane Field garden.

### Observation Trials with New Varieties of Hops

Outside farm trials of the Wye varieties bred by Professor Salmon, were discontinued, as it appears from the evidence available that the only varieties which could be generally recommended to growers at the present time are Bullion and Northern Brewer, and these varieties are already well-established in the industry. In future, the emphasis in outside farm trials is likely to be on the testing of new wilt tolerant varieties by the plant breeding section.

### Manurial Trials

The long-term manurial trial at Bodiam, Sussex, was maintained as were the mineral deficiency plots at Goudhurst, Kent. The data obtained from these and other trials, over a number of years, are now being examined with a view to assessing possible correlations between manuring, crop yield, soil analysis, leaf analysis and resin content, and to examine the possibility of defining, for hops, a range of critical levels for soil and plant nutrients. It is planned to publish a report on this work in 1958.

The sites for three new NPK trials, testing three levels of each nutrient in factorial experiments of $3^3$ design, were selected at Bodiam, Sussex, and Teynham, Kent, and harvested as uniformity trials. Two of the sites were considered reasonably satisfactory

from the yield data obtained (standard errors per plot of 9·7 per cent. and 8·9 per cent.), but on the third site the variability was excessive and a fresh site is to be selected in 1958.

These trials gave an opportunity of estimating the number of hills to be harvested, by random sampling, to give a valid estimate

TABLE 1

WYE FIELD VARIETY PLOTS, 1957

| Plot | Variety | Date | Hills | Bush. | Dry Wt. lb. | Yield (cwt. per acre) | Bush. per cwt. | |
|---|---|---|---|---|---|---|---|---|
| 22 | AOV52 | 27/9 | 38 | 85 | 95 | 27·01 | 100 | |
| 45 | OZ97a | 27/9 | 39 | 84 | 95 | 26·23 | 99 | |
| 6 | OQ22 | 16/9 | 40 | 103½ | 95 | 25·65 | 122 | |
| 72 | FF8 | 27/9 | 39 | 93½ | 91 | 25·21 | 115 | |
| 13 | OW76 | 16/9 | 40 | 97½ | 93 | 25·12 | 117 | |
| 73 | OA59 | 27/9 | 39 | 88½ | 89 | 24·74 | 111 | |
| 71 | CC77 | 27/9 | 42 | 89½ | 94 | 24·19 | 107 | |
| 66 | OV80 | 26/9 | 39 | 86 | 87 | 24·10 | 111 | |
| 76 | R1/38a | 26/9 | 39 | 73 | 86 | 23·82 | 95 | |
| 33 | OY43 | 17/9 | 38 | 95 | 83 | 23·65 | 128 | |
| 42 | WFB145 | 17/9 | 34 | 75 | 74 | 23·51 | 114 | |
| 57 | X69 | 26/9 | 40 | 98½ | 87 | 23·50 | 127 | |
| 62 | ADD50 | 26/9 | 37 | 82½ | 80 | 23·17 | 116 | |
| 40 | ON78 | 26/9 | 40 | 86 | 85 | 22·96 | 113 | |
| 65 | DD12 | 27/9 | 34 | 73 | 72 | 22·88 | 114 | |
| 29 | OW92 | 16/9 | 42 | 86½ | 87 | 22·38 | 111 | |
| 63 | OD18 | 17/9 | 60 | 157½ | 124 | 22·33 | 142 | |
| 46 | AOR43 | 17/9 | 40 | 77 | 82 | 22·15 | 105 | |
| 43 | OT22 | 16/9 | 37 | 86 | 75 | 21·90 | 128 | |
| 37 | WFI66 | 17/9 | 38 | 82 | 77 | 21·89 | 119 | |
| 24 | OK40 | 16/9 | 40 | 93 | 80 | 21·61 | 130 | Copper Hop |
| 9 | WFB135 | 13/9 | 39 | 81½ | 156 | 21·61 | 116 | Northern Brewer |
| 16 | WFB135 | 13/9 | 39 | 79½ | | | | |
| 15 | WFD20 | 13/9 | 39 | 94 | 169 | 21·23 | 116 | |
| 28 | WFD20 | 13/9 | 47 | 81½ | | | | |
| 5 | OB6 | 26/9 | 35 | 69½ | 68 | 20·99 | 114 | |
| 10 | WFH6 | 16/9 | 35 | 68½ | 68 | 20·99 | 113 | |
| 41 | WFD82 | 17/9 | 39 | 67 | 74 | 20·41 | 101 | |
| 38 | OM17 | 17/9 | 40 | 81 | 74 | 19·99 | 123 | |
| 39 | WFB117 | 17/9 | 40 | 72½ | 74 | 19·99 | 110 | |
| 64 | OR38 | 27/9 | 41 | 89½ | 75 | 19·76 | 135 | |
| 61 | WFH65 | 26/9 | 40 | 73 | 73 | 19·72 | 112 | |
| 11 | WFG19 | 13/9 | 40 | 81½ | 72 | 19·45 | 127 | Norton Court Golding |
| 2 | WFA90 | 16/9 | 38 | 66 | 68 | 19·33 | 109 | John Ford |
| 18 | WFA53 | 17/9 | 40 | 67½ | 71 | 19·18 | 106 | |
| 20 | 334a· | 17/9 | 40 | 81 | 71 | 19·18 | 128 | |
| 21 | OH77 | 26/9 | 44 | 69 | 78 | 19·15 | 99 | |
| 4 | EE64 | 16/9 | 40 | 69 | 69 | 18·64 | 112 | |
| 53 | AOM12 | 26/9 | 35 | 57 | 60 | 18·52 | 106 | |
| 31 | R20 | 26/9 | 40 | 71 | 68 | 18·37 | 117 | |
| 34 | WFH16 | 28/8 | 40 | 63½ | 68 | 18·37 | 105 | |
| 32 | WFD88 | 17/9 | 32 | 52 | 54 | 18·23 | 108 | |
| 27 | OV125 | 17/9 | 39 | 81½ | 64 | 17·73 | 143 | |
| 70 | K31 | 25/9 | 36 | 54 | 59 | 17·71 | 103 | |
| 56 | OR47 | 17/9 | 55 | 94½ | 90 | 17·68 | 118 | |
| 77A | R4/40a | 26/9 | 40 | 70½ | 63 | 17·02 | 125 | |
| 7 | WFG66 | 26/9 | 36 | 44 | 56 | 16·81 | 88 | |
| 25 | WFF90 | 16/9 | 35 | 57 | 53 | 16·37 | 104 | |
| 47 | DD57 | 25/9 | 38 | 60½ | 56 | 15·92 | 121 | |
| 59 | WFC130 | 27/9 | 37 | 54 | 51 | 14·89 | 119 | |
| 8 | OQ14 | 27/9 | 42 | 53½ | 56 | 14·39 | 107 | |
| 77B | OT100 | 26/9 | 33 | 33½ | 40 | 13·01 | 94 | |
| 69 | ACC5 | 26/9 | 40 | 49 | 46 | 12·42 | 119 | |
| 26 | X111 | 26/9 | 39 | 51½ | 44 | 12·19 | 131 | |

of the yield of an acre of hops. It was found that for the estimate to be within 5 per cent. and 10 per cent. of the true yield, approximately one-seventh and one-twenty-ninth of an acre, respectively, would have to be picked.

One observation trial on the growth of hops in grass, has been maintained. In 1957, the hops were irrigated and produced satisfactory growth and crop.

### Time of Application of Phosphate and Potash Fertilizers

This experiment was carried out on Fuggle hops grown in barrels, in standard hop soils previously used for experiments on soil acidity. The normal field procedure of applying all the phosphate and potash in mid-March was compared with treatments applying half the dressings of these fertilizers in mid-March and half in mid-July. Leaf samples were taken to assess mineral uptake and cone samples collected for resin analysis.

### Boron Nutrition

A limited amount of experimental work, in pot culture, was continued, in order to study further the effect of boron nutrition on the sugar and resin content of hop cones, and to investigate changes in level of the water-soluble boron content of different soil types—clay, brickearth and sand.

A report on the results obtained from these experiments, in the period 1955-57, is being prepared for publication in the Departmental Annual Report for 1958.

### Copper and Sulphur Fungicide Deposits on Leaves

The preliminary investigations on copper fungicide deposits started in 1956 were continued, a series of leaf samples being taken on six occasions from hops sprayed initially with copper oxychloride, and subsequently with Bordeaux mixture, at 50, 100 and 150 gallons per acre; the sprays supplied the same dosage of copper per acre. Sampling variations within each treatment were, in general, so large as to invalidate comparisons between treatments, but it may be said that the trend of the results suggested that the amount of copper deposited, per unit area of leaf, increased with increase in volume of spray applied although the *quantity* of copper applied, per acre, remained constant.

Samples were also taken from a fungicide trial, comparing copper oxychloride and Bordeaux mixture sprays at equivalent volumes

(300 gallons) per acre, but with the Bordeaux spray applying more than twice the amount of copper per acre. Analysis showed, nevertheless, that similar amounts of copper per unit area of leaf were obtained with both treatments.

With all the treatments examined, control of Downy Mildew appeared to be equally effective.

A study was made of the seasonal variation in copper content of hop leaves taken from plants receiving no copper sprays. The amounts of copper found ranged from 0·15 to 1·5 micrograms Cu per sq. cm. of leaf—values well below those found on leaves receiving standard sprays of either copper oxychloride or Bordeaux mixture.

Some preliminary studies were also carried out on the assessment of sulphur deposits on leaves. As with copper, large sampling variations were found within treatments and the method used for determining sulphur (developed at Long Ashton Research Station) although convenient and accurate, was too lengthy to permit the analysis of the large number of replicate samples required to assess valid treatment differences.

### Laboratory Work

A full programme of laboratory work has been maintained, including the analysis of over 100 soil samples and some 380 leaf samples for mineral nutrients and fungicide spray deposits, (involving some 1,800 separate determinations).

### Statistical Work

The statistical analysis of the results of departmental experiments, and of resin analysis and leaf analysis data from certain of the Rosemaund hop experiments, has been carried out.

# ORGANIC CHEMISTRY SECTION

## REVIEW OF THE YEAR'S WORK

E. W. Weston

### Experiments to Show the Effect of Shading Hops

An examination of the records of resin analyses over a number of years suggested that the resin content of hops was to a large extent governed by the amount of sunlight received. This effect was more noticeable with respect to values for the alpha resin than the beta resin.

The possibility that sunlight promoted the formation of the alpha resin, either from the beta resin as has been suggested by Schild and Raum (1956) or from some other precursor, could be tested by artificially shading hops.

Two methods of shading were adopted, neither giving complete exclusion of light. On one plant only (of the variety Bullion) the shading was by means of a large black cloth which was draped as a cylinder three feet high round the centre part of the plant. A number of hops were allowed to protrude through this covering although the main part of the bine to which they were attached remained in the shade.

The second method was applied to a number of plants and consisted of shading individual hops by clipping small paper bags over them. In this case the main part of the bine remained in the light as did all the leaves attached to it.

The shading was carried out by both methods at the beginning of August when the hops were small and they were picked during the third week of September. The hops were dried without sulphur treatment in a small kiln and then stored in polythene bags until required for analysis.

Resin and sugar analyses were as follows:

Plant with Black Cloth Shading

| Treatment | % $\alpha$-resin | % $\beta$-resin | % reducing sugars | Variety |
|---|---|---|---|---|
| Control above and below .. | 5·22 | 7·27 | 1·63 | Bullion |
| Behind cloth .. .. | 2·94 | 5·47 | 0·60 | ,, |
| Protruding from cloth .. | 3·54 | 5·59 | 1·56 | ,, |

HOPS SHADED BY PAPER BAGS

| Treatment | Plant No. | % α-resin | % β-resin | % reducing sugars | Variety |
|---|---|---|---|---|---|
| Shaded .. .. | E8 | 4·42 | 7·40 | 1·67 | Bullion |
| Control .. .. | | 4·84 | 6·26 | 2·12 | ,, |
| Shaded .. .. | E10 | 3·10 | 7·13 | 1·82 | Fuggle N |
| Control .. .. | | 2·97 | 4·26 | 2·18 | ,, |
| Shaded .. .. | E12 | 4·04 | 7·15 | 1·53 | ,, |
| Control .. .. | | 3·02 | 6·94 | 2·52 | ,, |

In the case of the cloth-shielding, both alpha resin and beta resin decreased as a result of the shading and the reducing sugars markedly so. Hops shielded by paper bags, however, showed much less decrease in sugars and an increase in both alpha and beta resins. This result may well be due to the fact that the cones were in general larger, and free from wind damage, which affected the controls to some extent.

| Treatment | Plant No. | % α-resin | % β-resin | % reducing sugars | Variety |
|---|---|---|---|---|---|
| Completely defoliated | B2 | cones shrivelled and died | | | John Ford |
| | B6 | 6·71 | 6·41 | 0·96 | ,, ,, |
| Controls .. .. | D6 | 6·37 | 6·75 | 2·20 | ,, ,, |
| Controls .. .. | E6 | 5·90 | 6·38 | 2·60 | ,, ,, |
| Controls .. .. | F6 | 7·44 | 8·05 | 1·23 | ,, ,, |
| Upper half defoliated | C2* | cones shrivelled and died | | | Northern Brewer |
| | C2† | 7·30 | 9·19 | 2·67 | |
| Control .. .. | D2 | 5·16 | 8·17 | 2·64 | ,, |
| Lower half defoliated | C5* | 7·50 | 7·04 | — | John Ford |
| | C5† | 6·20 | 5·50 | 1·49 | ,, ,, |
| Control .. .. | B5 | 5·71 | 6·84 | 1·70 | ,, ,, |
| Lower half defoliated | D3* | 3·99 | 6·60 | 2·98 | Bullion |
| | D3† | 1·97 | 4·36 | 2·44 | ,, |
| Control .. .. | C3 | 5·86 | 6·89 | 3·74 | ,, |

* Sample from upper half only. † Sample from lower half only.

### Defoliation

To assess the effect of leaves on the resin synthesis in the hop cone, either by regulating the supply of nutrient or modifying the shading, a number of plants were defoliated by hand when the cones had just formed. Some plants were defoliated completely; others were defoliated only on the upper or lower halves.

The resin and sugar contents of the treated plants together with control plants are shown at the foot of page 28.

Two chemical defoliants were also used, pentachlorophenol and chloro-acetic acid. A 1 per cent. solution in each case was neutralized with sodium hydroxide and sprayed on to the lower half of the plant. No mature cones developed on that part of the plant which was treated but hops were picked and analysed from the upper part.

| Treatment | Plant No. | % α-resin | % β-resin | % Reducing sugars | Variety |
|---|---|---|---|---|---|
| Pentachlorophenol | C10 | 3·44 | 4·36 | 2·42 | Fuggle N |
| ,, | C9 | 4·22 | 5·46 | 2·91 | ,, |
| Chloro-acetic acid | B10 | 3·51 | 4·65 | 3·16 | ,, |
| ,, ,, | B9 | 3·91 | 4·85 | 2·82 | ,, |
| Control .. .. | D9 | 3·40 | 4·72 | 1·27 | ,, |
| ,, .. .. | D10 | 4·16 | 4·76 | 2·28 | ,, |

Removing leaves from the lower half of a plant by chemical means does not appear to alter the resin or the reducing sugar contents of the hops appreciably.

Taking all treatments together (including the controls) and comparing the alpha resin and reducing sugars, the correlation coefficient is −·183 which is non-significant using 51 pairs of values for comparison.

### Sand Culture Experiment

Twenty cuts of Bullion hops were grown in sand in glazed earthenware pots 10 in.diameter and 10 in. deep. Each pot was given 500 ml. per day of the following complete nutrient solution, with trace elements added as required, until the plants were just in burr:

| | |
|---|---|
| Nitrogen 299 p.p.m. | Sodium 30 p.p.m. |
| Phosphorus 41 p.p.m. | Calcium 149 p.p.m. |
| Potassium 210 p.p.m. | Magnesium 40 p.p.m. |

The sand was then thoroughly washed with rainwater and the following treatments given:

$P_1K_1N_0$—P and K as for complete nutrient. No nitrogen.
$P_1K_1N_1$—P and K as for complete nutrient. N as for complete nutrient.
$P_1K_1N_2$—P and K as for complete nutrient. N twice complete nutrient.
$P_1K_1N_4$—P and K as for complete nutrient. N four times complete nutrient.
$N_1K_1P_0$—N and K as for complete nutrient. No P.
$N_1K_1P_2$—N and K as for complete nutrient. P twice complete nutrient.
$N_1K_1P_4$—N and K as for complete nutrient. P four times complete nutrient.
$N_1P_1K_0$—N and P as for complete nutrient. No K.
$N_1P_1K_2$—N and P as for complete nutrient. K twice complete nutrient.
$N_1P_1K_4$—N and P as for complete nutrient. K four times complete nutrient.

The hop cones were picked when ripe, dried without sulphuring, and alpha and total soft resins were determined, together with reducing sugars in the cones.

The analytical results are as follows (each result mean of two values):

| Treatment | % α-resin | % Total soft resins | % Reducing sugars |
|---|---|---|---|
| $P_1K_1N_0$ .. .. .. | 4·04* | 12·27* | 5·23 |
| $P_1K_1N_1$ .. .. .. | 3·95 | 11·08 | 3·41 |
| $P_1K_1N_2$ .. .. .. | 4·10 | 11·07 | 3·25 |
| $P_1K_1N_4$ .. .. .. | 3·49 | 9·08 | 2·60 |
| $N_1K_1P_0$ .. .. .. | 4·55 | 10·33 | 4·53 |
| $N_1K_1P_2$ .. .. .. | 3·11* | 9·08* | 3·84* |
| $N_1K_1P_4$ .. .. .. | 4·28 | 11·20 | 3·45 |
| $N_1P_1K_0$ .. .. .. | 3·40 | 10·17 | 3·12 |
| $N_1P_1K_2$ .. .. .. | 3·87 | 10·20 | 3·59 |
| $N_1P_1K_4$ .. .. .. | — | — | — |

* One value only.

The values obtained for reducing sugars follow the expected pattern in that they are inversely related to the nitrogen and the phosphorus applied, and directly related to the applied potassium.

The alpha resin percentage is positively correlated with sugar content although not significantly so.

The results from all the experiments reported above appear to show no general close connection between resins and reducing sugars in the hop cone. The reducing sugar content can, in fact, vary much more than shown above without appreciably affecting the resin

content. For example, analyses of a series of Fuggle N hops of 1957 growth from a manurial experiment give the following results:

| Plant No. | % α-resin | % Total soft resins | % Reducing sugars | Plant No. | % α-resin | % Total soft resins | % Reducing sugars |
|---|---|---|---|---|---|---|---|
| 1. | 3·72 | 10·58 | 7·20 | 23. | 3·93 | 11·06 | 9·82 |
| 2. | 3·25 | 8·93 | 6·65 | 25. | 2·66 | 7·99 | 10·67 |
| 3. | 3·66 | 10·64 | 5·77 | 26. | 3·11 | 8·08 | 11·76 |
| 4. | 3·31 | 9·05 | 7·97 | 27. | 3·51 | 10·01 | 6·84 |
| 5. | 3·34 | 9·43 | 7·74 | 28. | 3·00 | 9·27 | 5·39 |
| 6. | 3·63 | 10·57 | 6·78 | 29. | 3·34 | 9·97 | 6·52 |
| 7. | 3·84 | 10·16 | 5·91 | 30. | 3·55 | 9·68 | 9·10 |
| 8. | 3·93 | 11·19 | 6·42 | 31. | 2·72 | 7·74 | 12·95 |
| 9. | 3·66 | 9·36 | 11·99 | 34. | 3·32 | 9·63 | 7·86 |
| 10. | 3·92 | 8·91 | 11·94 | 35. | 3·76 | 10·99 | 6·86 |
| 11. | 4·55 | 11·62 | 8·36 | 36. | 2·91 | 8·62 | 4·51 |
| 12. | 3·34 | 8·66 | 8·79 | 37. | 3·26 | 8·88 | 9·26 |
| 13. | 3·76 | 10·62 | 9·37 | 38. | 4·07 | 11·44 | 7·39 |
| 14. | 3·90 | 10·55 | 3·74 | 39. | 2·90 | 8·61 | 7·91 |
| 15. | 2·75 | 7·73 | 11·05 | 40. | 2·75 | 8·88 | 12·47 |
| 17. | 2·93 | 8·83 | 2·91 | 41. | 3·17 | 9·22 | 10·58 |
| 18. | 3·78 | 11·38 | 9·04 | 42. | 2·64 | 7·61 | 9·73 |
| 19. | 3·79 | 10·86 | 8·08 | 44. | 3·13 | 8·89 | 6·32 |
| 20. | 3·98 | 12·29 | 6·03 | 45. | 3·88 | 11·26 | 5·87 |
| 21. | 3·41 | 9·69 | 7·56 | 46. | 3·57 | 10·02 | 7·20 |
| 22. | 4·25 | 11·60 | 5·55 | | | | |

Comparing alpha resins with reducing sugars a correlation coefficient of $-0{\cdot}28$ is obtained which is not significant for 41 pairs of values.

It must be concluded from this and from work in previous years that there is no direct connection between the content of reducing sugars in the hop cone and the content of alpha resin. It may be that as a result of certain treatments of the hop plant, e.g. manurial treatment, an indirect relation occurs. In other cases a relationship may be observed which is due to gross disturbance of the growth such as would occur with defoliation or excessive shading.

### Resin Analyses

Resin analyses have been carried out on the 1957 crop on behalf of other organizations as well as for current research within the Department in addition to those listed above.

These have been as follows:

| | |
|---|---|
| Institute of Brewing Challenge Cups .. | 86 |
| Samples from Rosemaund Experimental Farm | 86 |
| Hop Department Plant Breeding Trials .. | 241 |
| Hop Department Cultural and Manurial Trials | 123 |
| Miscellaneous .. .. .. .. .. | 35 |
| Total .. .. .. .. | 571 |

## Reference

Schild, E., and Raum, H. (1956). Papierchromatographische Studien uber die Bittersauren und Harze des Hopfens, (Paper-chromatographic studies on the bitter acids and resins of hops). *Brauwissenschaft*, Vol. 9, p. 150.

# PLANT PATHOLOGY SECTION

## REVIEW OF THE YEAR'S WORK

H. S. Darling, Dorothy M. Derbyshire and F. H. Beard

(*a*) *Systemic insecticides and control of the Hop Aphis* (*Phorodon humuli*)

In collaboration with the Department of the Government Chemist a study was made of the uptake of the systemic insecticide dimefox (bis dimethylaminofluorophosphine oxide) by hops when applied to the soil over the crown of the hill. The results of this work have already been discussed elsewhere (Laws and Darling, 1958). Established hills of clonal Goldings were used, to each of which the standard commercial dose of 0·5 gm. active ingredient in 120 ml. water was applied on May 31st, 1958. A second application at 0·25 gm. per hill, also in 120 ml. water, was made to some of the plants on July 19th, 1957.

The plants used in this investigation were grown at Wye on brickearth-type soil at a spacing of 6 ft. 6 in. square with "open umbrella" stringing on wirework 14 ft. 6 in. high. Samples of leaves from different heights were collected at intervals from June 3rd to August 9th; samples of ripening cones and of dried hops were also taken. All these samples were analysed by the Government Chemist, dimefox concentrations being recorded in parts per million of the green weight except in the case of the dried cones. The results from the plants receiving the single application on May 31st are tabulated below:

| Date of sampling (No. of days from application given in brackets) | Dimefox p.p.m. | |
|---|---|---|
| | Lower leaves (3 ft.–4 ft. 6 in.) | Upper leaves (7 ft.–12 ft.) |
| June 3rd (3) | 3·5 | — |
| June 11th (11) | 2·2 | 1·2 |
| June 18th (18) | 2·5 | 3·2 |
| July 1st (32) | 1·6 | 0·9 |
| July 7th (39) | 1·9 | 1·0 |
| July 16th (47) | 0·9 | 1·0 |
| July 22nd (53) | 0·8 | 0·6 |
| July 27th (58) | 1·0 | 1·1 |
| August 9th (72) | 0·1 | 0·3 |

Dimefox concentrations increased slowly to a recorded maximum on June 18th. The slow uptake may have been due to poor growing conditions prevailing at the time, the weather being dry with cold winds. During July this single application on May 31st maintained dimefox levels of the order of 1·0 p.p.m. in the leaves, a value which appeared to give satisfactory aphid control. The samples taken on August 9th, 72 days after application, showed a sharp drop in concentrations to 0·1–0·3 p.p.m.

The second application of 0·25 gm. per hill on July 19th caused a temporary increase in dimefox concentration in the treated plants as shown by the data tabulated below:

| Date of sampling (No. of days from application given in brackets) | Dimefox p.p.m. | |
|---|---|---|
| | Lower leaves (4 ft. 6 in.) | Upper leaves (12 ft.) |
| July 16th (—) .. .. .. | 0·9 | 1·0 |
| July 19th (0) .. .. .. | Dimefox applied at 0·25 gm. per hill | |
| July 22nd (3) .. .. .. | 2·9 | 2·0 |
| July 27th (8) .. .. .. | 1·0 | 6·0 |
| August 9th (22) .. .. .. | 0·2 | 0·4 |

The effect of this second application was short-lived. By August 9th, 22 days after the second treatment, concentrations in the leaves had dropped to 0·2–0·4 p.p.m. or little above the levels of 0·1–0·3 p.p.m. recorded in the plants receiving the first treatment only. Presumably this fall in dimefox concentrations was due in part at least to the large amount of plant growth in August when laterals grew out and the cones developed. Such growth probably dispersed the dimefox available over an increasing volume of plant tissue giving a dilution effect. It is possible, however, that physiological and biochemical changes in the plant may also have been involved.

This rapid drop in dimefox concentrations observed in hop plants in August is of importance since it suggests that a late application of this expensive insecticide may be of little advantage. In this connection it should be noted, however, that a survey of ripening cones on the treated plants was made at the end of August. This showed that while 2 per cent.–3 per cent. of the cones on the plants receiving the single application on May 31st only were lightly infested, no aphids were found in the cones of the plants which also received the second application on July 19th. The additional

dimefox would appear to have had sufficient effect to prevent aphids from infesting the developing cones.

Samples of ripening cones, taken on September 2nd showed 0·1 and 0·3 p.p.m. dimefox respectively (green weight basis) in the plants receiving one and two applications of the insecticide. Harvesting took place on September 16th and samples of commercially dried hops showed 0·13 and 0·33 p.p.m. dimefox (dry weight basis) respectively in cones from the plants receiving the single and double application. The last two values correspond to 0·03 and 0·07 p.p.m. respectively in terms of fresh green weight.

In addition to the above work, an examination was completed of data from five East Kent hop farms on the use of systemic insecticides and the green bushel/dried cwt. ratio. A summary of the results of this examination has already been published (Darling, 1958). A fuller account is given in an article on page 98 of this report.

(*b*) *Spraying trials on the control of Hop Downy Mildew* (*Pseudoperonospora humuli*)

The replicated spraying trial on Downy Mildew control, which was carried out in 1955 and again in 1956 (Darling and Derbyshire; 1956, 1957) was repeated in 1957. Once again the variety Petham Golding was used. The lay-out, management and spraying methods were unchanged from previous years. The treatments were:

| | |
|---|---|
| Bordeaux Mixture: | 10 lb. copper sulphate crystals and 15 lb. lime in 100 gallons water. |
| Copper Oxychloride: | 3 lb. commercial formulation in 100 gallons water. |
| Captan: | 2½ lb. wettable powder (50 per cent. active ingredient) in 100 gallons of water. |

During May and June all plots received three routine low volume (50 gallons/acre) treatments with wettable sulphur and copper oxychloride sprays. The latter chemical was applied at 3, 4½ and 6 lb. per acre respectively on these occasions. On May 31st the systemic insecticide dimefox was applied via the soil to all plants.

The trials commenced on July 1st, 1957, and the experimental sprays were applied by hand-lance four times during July and August to the 60 hills in each treatment on the following dates at the volumes stated:

July 15th at the rate of 300 gallons per acre.
July 25th at the rate of 300 gallons per acre.
August 7th at the rate of 350 gallons per acre.
August 16th at the rate of 300 gallons per acre.

The spring and early summer were dry and sunny with cold winds, and growth at first was slow. With the coming of warmer weather in late June, growth improved and subsequent bine development was normal. July and August were wet and cloudy with near average temperatures.

The incidence of Downy Mildew remained very low throughout the season. No spikes were recorded in any treatment during the summer, and there was little if any evidence of infection in the cones.

The plots were picked on September 18th when, as in other years, the captan-treated cones before drying were brighter and more pleasing to the eye than those from the two copper treatments. Yield data, which showed no significant differences, were as follows:

| Treatment | Green bushels per acre | Cwt. dried hops per acre | Green bushels per dried cwt. |
|---|---|---|---|
| Bordeaux mixture | 2257 | 19·6 | 115 |
| Copper oxychloride | 2264 | 19·7 | 115 |
| Captan .. .. | 2276 | 20·0 | 114 |

Samples of cones from the three treatments were analysed for resin content with the following results:

| Treatment | Total Soft Resins | α-Resin |
|---|---|---|
| | % | % |
| Bordeaux mixture .. .. .. | 13·19 | 5·53 |
| Copper oxychloride .. .. .. | 12·51 | 5·38 |
| Captan .. .. .. .. .. | 12·23 | 5·34 |

These resin values are all within the expected range of variation for Golding hops.

The treated hops were submitted to the College hop factor for commercial examination and appraisal. No clear-cut differences could be found and the hops from all three treatments received equal valuation in the Grade I plus bonus category.

This trial is to be discontinued; the results which have emerged may be summarized as follows:

(1) *Downy Mildew control:* in a non-replicated trial on Goldings at Wye in 1954 with heavy incidence of Downy Mildew, captan was observed to give as effective control of the disease as Bordeaux mixture. In replicated trials in 1955, 1956 and 1957 captan continued to give as good control as Bordeaux mixture, but it should be noted that in these three years the disease was not so severe as in 1954.

(2) *Yield of dried hops:* yield data in cwt. of dried hops for 1955, 1956 and 1957 are set out below:

| Treatment | 1955 | 1956 | 1957 |
|---|---|---|---|
| Bordeaux mixture .. .. .. | 20·8 | 4·9 | 19·6 |
| Copper oxychloride .. .. | 20·6 | 5·4 | 19·7 |
| Captan .. .. .. .. | 22·3 | 5·4 | 20·0 |

No statistically significant yield differences were recorded but it is perhaps worthy of note that the captan-treated plants consistently out-yielded those sprayed with Bordeaux mixture. It should also be noted that in 1956 all yields were drastically reduced by wind damage.

(3) *Quality of dried hops:* Chemical analysis for resin content has failed to reveal any treatment effects. Commercial appraisal of dried samples in the Borough in 1955 reported the captan-treated hops to be superior in appearance to those from the two copper treatments; no such differences were observed in 1956 or 1957. Small-scale brewing trials by the Brewing Industry Research Foundation have shown that while captan residues on the cones appear to be of little or no importance in copper-hopping, they can cause serious tainting in beer if used in dry-hopping. On this account captan should not be applied to the crop later than the middle of August.

In addition to the replicated spraying trial described above, a small-scale observation trial was carried out on Golding hops using zineb (zinc ethylene bis-dithiocarbamate) as a spray. This fungicide appeared to give satisfactory control of Downy Mildew, but in view of the very low incidence of the disease in 1957 this finding should be treated with reserve. Cones contaminated with zineb residues were tested by the Brewing Industry Research Foundation; copper-hopping and dry-hopping trials failed to reveal any taint or harmful effect in beer brewed with these hops.

(*c*) *Hill dusting trial*

During the winter of 1956–57 the hills of the varieties Early Bird, Eastwell and Petham Golding from a grubbed area of Silks garden were examined for Downy Mildew infection. It was found that despite routine control measures on the aerial parts of the plants, severe rotting of the hills had occurred and bine production was increasingly erratic each season (Beard and Derbyshire, 1957).

Since it is still not known whether infection by Downy Mildew is the sole cause of the rotting and death of hills of susceptible varieties, two experiments have been planned to investigate the severity of rootstock infection by this fungus. In addition, a trial has been started to study the effect of dusting hills with two fungicides. The treatments have been superimposed on an area of clean Golding setts planted in March, 1957, in the garden from which the infected hills were previously grubbed. It was considered essential that the dusting trial should be carried out on hills which were disease-free at the start of the experiment, although the soil in which they were planted was contaminated with infected plant debris.

The powder was shaken on to the base of the plants from a muslin bag, and the treatments were as follows:

(*a*) Bordeaux powder applied early in the season on April 4th, 29th and May 27th.
(*b*) Bordeaux powder applied at monthly intervals during the season, the first application being on April 4th and the sixth on August 30th.
(*c*) 7½ per cent. captan dust applied at monthly intervals as in treatment (*b*).
(*d*) Untreated control.

Records of spike production will be kept over a period of years to determine whether the technique is valuable in reducing the amount of inoculum reaching the hill. The early application of fungicide may have a direct effect in protecting the developing young shoots from spores produced by early spikes, while the monthly fungicide treatment may give protection to the dormant buds on the hills throughout the growing season.

(*d*) *Propagation and inoculum supply*

The plants required for Downy Mildew resistance tests were propagated from lateral cuttings taken in July and August.

Field infection was very limited in 1957, and in consequence the

fungus was maintained throughout the season on detached leaves in the laboratory.

Plants susceptible to Downy Mildew have been successfully grown during the winter in a heated glasshouse equipped with lamps for supplementary lighting (Derbyshire and Dixon, 1957) and a small supply of inoculum has been kept on young leaves from these plants.

(*e*) *Testing for resistance to Downy Mildew*

In testing for resistance to Downy Mildew, infection of the rootstock, young shoots, leaves and cones has been considered. The fungicide spray programme is designed ultimately to give protection to the developing hop cones, but during the growing season the aerial parts of the plants are also protected. It is possible that the same level of resistance or susceptibility may not be shown in all parts of a plant and therefore, at present, several resistance tests on various parts of a plant are being carried out. Later the level of resistance may be established by a single test.

Tests on detached leaves have been continued as previously described (Darling and Derbyshire, 1957), and two seedling families, derived from highly resistant female parents obtained from Dr. Zattler at Munich, have been assessed for Downy Mildew resistance. No male plant showing the same high degree of resistance as the female parent has yet been found.

Young shoots and rootstocks have also been assessed for resistance to Downy Mildew. Plants were selected which had previously shown either marked susceptibility or resistance in the leaf test in order that the response to infection of different parts of the plant could be examined. Buds emerging through the soil in the spring from clean rootstocks potted in sterilized compost, were inoculated with a spore suspension of the fungus, and kept in a humid atmosphere for several days. Spike development was noted and the plants continued growth in the glasshouse. Later the plants were examined, and freezing microtome sections made to trace mycelium in the shoot and rootstocks.

In susceptible varieties such as Golding the whole shoot developing from an inoculated bud became distorted, and a characteristic spike was formed. In Fuggle, growth of the bud was not retarded so quickly and several internodes of normal length developed before a spike terminated the growth of the shoot. Despite the use of a heavy inoculum, Dr. Zattler's resistant plants showed very marked resistance to bud infection. No spikes were

formed and no mycelium was found in any of the inoculated shoots of these plants, although slight leaf infection was observed.

The extent of rootstock infection was variable, in the small number of plants of each variety which could be tested. But in a number of susceptible plants mycelium from diseased shoots invaded the rootstocks, and strap-cut infection was also found. Where only slight infection of the shoots occurred, the rootstocks frequently remained free from mycelium. Bud and rootstock infection appear to be of such importance in the annual cycle of disease caused by Downy Mildew that tests similar to those described will be continued in the selection of resistant varieties.

A test designed to examine the resistance of seedlings at the four leaf stage to Downy Mildew was attempted during 1957. Seeds from a susceptible commercial variety, and from a Downy Mildew resistant parent was sown, and the young seedlings sprayed with spore suspension of the fungus. None of the seedlings from the susceptible parent remained free from the disease, but fourteen of those from the resistant parent were selected and planted out for later tests. From this preliminary work it appears that the large number of susceptible seedlings obtained from open pollination of resistant female plants can be eliminated at an early stage of growth, while resistant plants may be selected for further examination.

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# CROP PHYSIOLOGY SECTION

## REVIEW OF THE YEAR'S WORK

I. H. Williams

The scope of research covered by the title "crop physiology" is discussed in Appendix IV of this report. Work of this nature on hops was not initiated at Wye College until early July when half of the annual cycle of the crop was already completed. Opportunities for research in 1957 were correspondingly limited but progress has been made.

### Growth Studies

These are considered to be of fundamental importance. Preliminary studies were carried out on the growth and development of two-year old plants of Fuggle N growing under field conditions. This work has provided a basis of experience for a programme of similar studies on a larger scale planned for 1958 and succeeding years.

### Propagation

A series of experiments designed to study methods of breaking dormancy in seed harvested in 1957 were carried out in collaboration with the organic chemist in the winter of 1957-58. The results of this work, which confirm the effectiveness of a period of low temperature treatment, are discussed elsewhere in this report on page 108. The study of methods for maintaining vegetative clones during the winter under glass, which was initiated by the pathology section (Derbyshire and Dixon, 1957), was continued.

### Dormancy and Nutrient Reserves

Preliminary research was carried out on the onset of dormancy in vegetative growth and the associated accumulation of storage tissue in the rootstock. In collaboration with the organic chemist, techniques are being studied for investigating the changes which occur during the year in such storage tissue.

Irrigation

Modern concepts of irrigation and their application to the hop crop under English climatic conditions are discussed in Appendix V of this report. Plans have been made for a large-scale experiment to be carried out in 1958 at Bodiam with the co-operation of the staff of the Guinness Hop Farms Ltd.

Reference

Derbyshire, Dorothy M. and Dixon, Evelyn M. (1957). Notes on growing hops under glass during the winter of 1956-57. *Rep. Dept. Hop Res. Wye Coll. for 1956*, p. 73.

# INHERITANCE OF RESIN CHARACTERS IN HOPS

## II. TRIPLOID SEEDLINGS OF FUGGLE

R. A. Neve

Summary

Resin contents of triploid seedlings raised from crosses between tetraploid Fuggle N and six wilt-tolerant males were determined.

The mean values for the seedling families are in all cases higher than for the Fuggle parent. Most of this difference can be accounted for as a direct result of the lower seed content in the cones of the triploid plants.

Smaller differences occur between families and indicate the relative value of the different male parents in transmitting resin characters.

The variation within and between families is such as to suggest that genetic control of resin characters is effected by a large number of genes each producing a small effect.

The importance of the results to the hop breeding programme is discussed.

### Introduction

Most of the commercially important characters of hop varieties are difficult to assess. Hop aroma varies greatly with the condition of the sample and at present depends too much upon the opinion of the judge for its genetic basis to be determined. Yield, too, is greatly influenced by environmental factors, and its accurate determination for a large number of varieties is difficult. On the other hand soft resin content, which is a very important attribute of the hop, is a relatively constant characteristic of a variety and it can be accurately measured.

In an earlier paper (Farrar, Neve and Weston, 1956) it was shown that attempts to assess the breeding value of male hops by counting the number of resin glands on the anthers were not successful. In the absence of any means of direct assessment it is necessary to resort to progeny testing to determine which of the available male plants will prove the most useful parent.

The hop breeding programme at Wye is aimed primarily at producing new varieties tolerant to *Verticillium* wilt, and in consequence the most important of the available males are those which are themselves tolerant to this disease. The results to be described were obtained from crosses between six of these males and a tetraploid form of Fuggle N. The resulting triploid seedlings

are semi-seedless (Farrar, 1956) and are expected to show a closer resemblance to the female parent than would be the case if a diploid female parent was used (Dark, 1953; Neve and Farrar, 1955; Neve, 1956). It would have been valuable to compare these six families with corresponding diploid families, but facilities were not available to handle the extra plants necessary. Such comparisons between diploid and triploid families are, however, now in progress.

## Material

The female parent in each case was colchicine-treated Fuggle N which had been shown to be tetraploid in nature. The six wilt-tolerant males used were:

| | |
|---|---|
| OL45 | An open pollinated seedling of BB1 (a Canadian wild hop). |
| II61 | An open pollinated seedling of 411 (a seedling of BB1). |
| OB79 | An open pollinated seedling of a New Mexican wild hop. |
| 211 | An open pollinated seedling of a New Mexican wild hop. |
| 321 | An open pollinated seedling of a New Mexican wild hop. |
| 15 | Parentage unknown. |

The crosses were made in 1955, the female plants being grown in a glasshouse, and muslin sleeves were used to exclude contaminant pollen. These sleeves have proved unsatisfactory in the field, but from observations on the resulting families it appears that the level of contamination under glass was low.

The seeds were sown in the spring, and the seedlings planted out in the summer of 1956. Few plants flowered that season, but nearly all plants flowered in 1957. In the smaller families (from OB79, 211 and 321) samples were collected from all the female seedlings which yielded sufficient material for resin analysis. In each of the three larger families (from OL45, II61 and 15) samples were collected from the first 50 seedlings which yielded sufficient material in each family. Samples were also taken from six control plants of diploid Fuggle N, one of which was planted at the beginning of each family.

Resin analyses were carried out in December, 1957. One sample from the OL45 family was lost, so only 49 results are available in that case.

## Results

The results of the resin analyses are shown by means of the histograms in Fig. 1. On these histograms the mean values obtained from the Fuggle controls are indicated by a dashed line. It is clear

that the mean values for each family are considerably higher than for the controls.

Statistical analysis, which has been confined to the results for alpha resin, shows that the differences between the four largest families and the controls are significant ($P < \cdot 01$).

Since resin content is measured as a percentage of dry weight it is to be expected that seeded hops will have a lower resin content than corresponding semi-seedless ones, and it is important to assess how much of the observed differences between the controls and the seedling families should be attributed to the seedless nature of the latter. Farrar (this report, p. 50) has shown that the difference between the seed contents of these diploid and triploid hops is of the order of 20 per cent. of the total weight of kiln dried hops. On the basis of this figure, the recorded values for resin content of the Fuggle controls have been adjusted to indicate what the approximate resin content of a hypothetical triploid Fuggle plant would be. In Table 1 the observed and adjusted values for Fuggle are compared with the mean values of each family.

TABLE 1

| | α-resin | β-resin | T.S.R. |
|---|---|---|---|
| II61 family. Mean value .. .. | 5·66 | 7·49 | 13·15 |
| OB79 ,, ,, ,, .. .. | 5·41 | 7·42 | 12·83 |
| 211 ,, ,, ,, .. .. | 5·85 | 6·72 | 12·57 |
| 321 ,, ,, ,, .. .. | 4·76 | 6·46 | 11·22 |
| OL45 ,, ,, ,, .. .. | 4·72 | 6·99 | 11·71 |
| 15 ,, ,, ,, .. .. | 4·69 | 6·50 | 11·20 |
| All seedlings mean value .. .. | 5·09 | 7·00 | 12·09 |
| Fuggle. Observed value .. .. | 3·97 | 5·21 | 9·18 |
| Fuggle. Adjusted value .. .. | 4·96 | 6·51 | 11·47 |

The adjusted values are indicated on the histograms in Fig. 1 by dotted lines. It will be noticed that the adjusted values lie close to the family mean values in all cases. Thus it appears that the greater part of the increase in resin content of the seedling families is a direct result of their lower seed content, and not of inherited characters. Nevertheless, there are smaller differences between families and these are significant in a number of cases. The II61 family has a significantly higher level of α-resin than the OL45, 321, or 15 families, and the family from OB79 is significantly richer in α-resin than are the seedlings of OL45 or 15. These differences are presumably of genetic

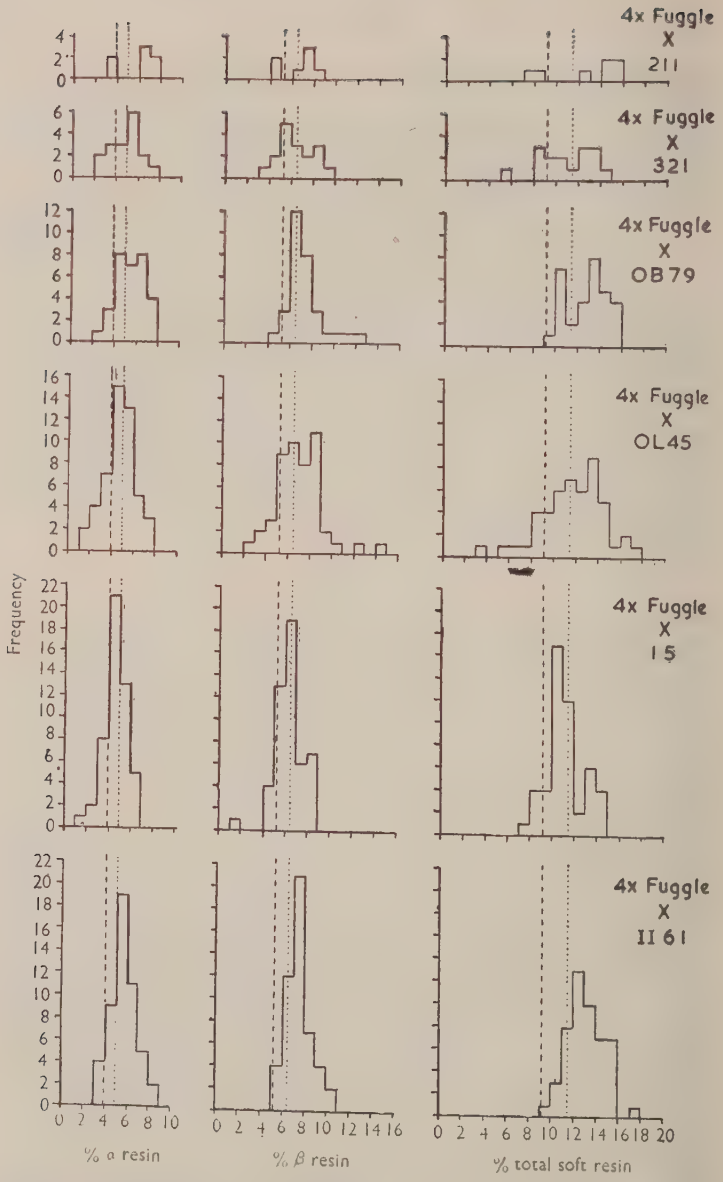


FIG. 1.

Frequency distribution of percentage soft resins in seedlings of six families. Dashed lines indicate percentage resin in Fuggle control plants and dotted lines the corresponding values after adjusting for seed content.

origin and serve as a measure of the relative value of these male plants as parents in a breeding programme.

Scatter diagrams to illustrate the relationship between α-resin and β-resin contents of the seedlings of the four largest families are shown in Fig. 2. In the OL45 family there is a positive correlation which is significant at the 5 per cent. level, but the other families show no significant correlation. Thus it seems clear that α- and β-resin contents are normally inherited quite independently, and that only in certain circumstances may there be an association between them. However, the level of significance is such that this association cannot be considered to have been established until further evidence is available.

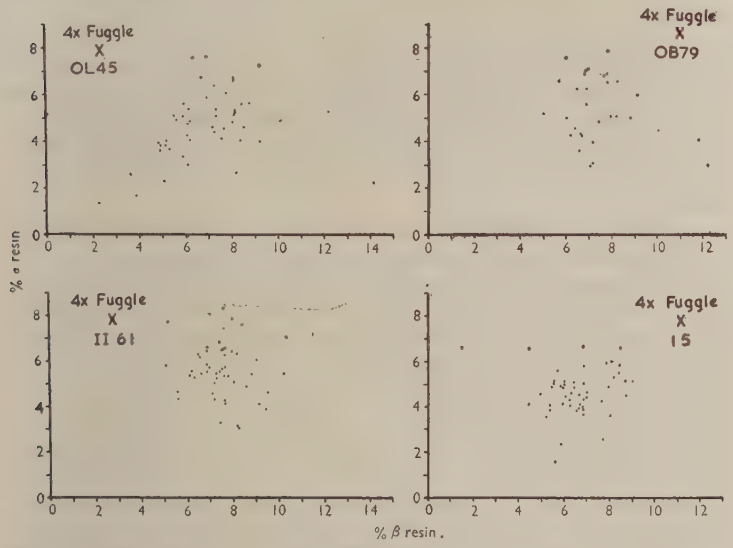


Fig. 2.

Scatter diagrams showing the relationship between α-resin and β-resin content of seedlings from four families

## Discussion

The results obtained from this progeny test are of considerable importance to the hop breeding programme at Wye. This programme relies to a large extent on the production of triploid seedlings to achieve its purpose. It has been recognized (Neve and Farrar, 1955) that the main disadvantage of a triploid variety would be the loss

of yield which would result from the absence of seed, which is, however, of no value to the brewer. Higher prices per hundredweight may be necessary for triploid varieties, but these can only be justified if it can be shown that the percentage of useful materials such as soft resins and hop oils are higher in a triploid than in a corresponding diploid variety. The results presented here suggest that this condition is likely to be satisfied in the case of the soft resins.

The results also provide, for the first time, information on the transmission of resin characters by some of the male hops being used in the breeding programme. There is a great need for this, and further, information to make a more efficiently planned programme possible.

Mention was made in the earlier paper (Farrar, Neve and Weston, 1956) of the lack of correlation between the α-resin and β-resin contents of a group of seedlings. The results presented here confirm this lack of correlation except in one family. Special factors may be involved in this one case, but speculation on possible causes would be premature unless the relationship is confirmed by further trials.

Significant differences in resin content have been demonstrated between families which indicate that genetic differences are involved. The histograms in Fig. 1 make it plain that there is no segregation of the seedlings into distinct classes such as would be expected if these genetic differences involved only one or two pairs of genes. The indications are, on the contrary, that resin content of hops is polygenically controlled; that is to say that many pairs of genes are involved, each one producing a small, but additive, effect. It has been pointed out (Neve, 1956) that the use of a tetraploid female hop parent is likely to be most efficient when the number of genes determining desirable characters in the female is high in proportion to the number of genes controlling new characters which it is desired to introduce from the diploid male parent. In view of this, the indication that resin content, at least, is controlled by many genes is of considerable interest.

Thanks are due to Mr. E. W. Weston for carrying out the many analyses involved in this work.

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# SEED CONTENT OF TRIPLOID HOPS: FURTHER INVESTIGATIONS

R. F. Farrar

Summary

Triploid seedlings of Fuggle are shown to have a lower seed content than diploid Fuggle.

The results of petal and seed counts are given, and show that while triploids have a lower seed content than diploids, they have a similar number of petals.

A commercial technique for rapid seed content assessment is compared with that used in earlier work on triploids, and is shown to give lower results.

Samples of continental seedless hops are compared with triploids, and their seed content is shown to be lower than can be expected from the average triploid.

The results are discussed in relation to the possible use of triploids as commercial varieties.

## Introduction

In the first report on investigations into the seed content of triploid hops (Farrar, 1956), the need for further work was noted, and broad lines upon which this could run were given. The original hills which provided the samples for the earlier work were lost, the garden in which they were sited being grubbed in the winter of 1955 due to an outbreak of progressive *Verticillium* wilt. This fact, together with subsequent alterations in experimental layout and the picking programme, broke the continuity of some of the information on the seed content of triploids as they age. Nevertheless, samples were collected from other material, and it was possible to follow several lines of study. These can be summarized as follows :

(1) Seed content of Fuggle triploids.

(2) Petal and seed numbers in diploids and triploids.

(3) A commercial method of seed content assessment and its application to triploids.

(4) Seed content of continental "seedless" hops compared with triploids.

The hills at Wye from which cones were collected, were growing

in a garden containing, by commercial standards, a high proportion of males (approximately 1 in 30); these males covered a wide range of seasons. All the samples referred to are of kiln dried cones.

### Seed Content of Fuggle Triploids

The earlier investigations into the seed content of triploids were carried out on open pollinated seedlings from tetraploid Bullion. The extension of this routine analysis, to triploids from another variety, was facilitated by the planting out, in 1956, of a large series of seedlings resulting from crosses made between tetraploid Fuggle N and diploid wilt-tolerant males. From a number of these seedlings, and from diploid Fuggle N plants of comparable size and vigour, samples were collected and analysed in 1956 and 1957.

In 1956 the seedlings, being in their first year, produced few cones and the samples in every case but one represented the complete crop. Two of the three Fuggle control plants produced no cones in that year.

In 1957 the hills were better established and two samples of 10 gm. each were collected from them, with the exception of one triploid which was over-ripe and not included.

The results of the analyses are shown in Table 1, and two features are at once apparent. Firstly the seed content of the triploid seedlings of Fuggle was very much lower than that of diploid Fuggle N growing under the same conditions ; and secondly, the extremely low results for the 1956 triploid samples compared with those for 1957, indicate that seed assessment of seedlings in their first year may be of little value. The low results for first year seedlings may well be due to their tendency to flower late, when most of the males have finished throwing pollen.

### Petal and Seed Numbers in Diploids and Triploids

The low seed content of triploid cones could, in part at least, be due to a difference in structure from diploid cones.

As described by Burgess (1956), a hop cone consists of groups of bracts and bracteoles borne alternately along the central axis or strig. There are theoretically two bracts and four bracteoles in each group, and a simple female flower containing a single ovary is enclosed at the base of each bracteole. It follows that a cone with an abnormally reduced number of bracteoles would bear a similarly reduced number of ovaries, and subsequently of seeds.

TABLE 1

RESULTS OF SEED CONTENT DETERMINATIONS CARRIED OUT ON DIPLOID AND TRIPLOID FUGGLES IN 1956 AND 1957

| Sample | Ploidy | 1956 | | 1957 (Average of pairs of 10 gm. samples) |
|---|---|---|---|---|
| | | Weight of Sample (gm.) | Weight of Seed % | Weight of Seed % |
| Fuggle .. | 2x | 2·3 | 16·5 | 24·1 |
| Fuggle .. | ,, | No crop | — | 24·1 |
| Fuggle .. | ,, | No crop | — | 26·9 |
| Diploid Means .. | | 2·3 | 16·5 | 25·0 |
| RP96 .. | 3x | 7·0 | 0·6 | 5·1 |
| RQ52 .. | ,, | 6·5 | Nil | 5·6 |
| RR38 .. | ,, | 6·0 | 0·7 | Not picked |
| RR66 .. | ,, | 10·0 | 0·4 | 5·4 |
| RR83 .. | ,, | 2·8 | Nil | 3·4 |
| RR103 .. | ,, | 4·5 | 0·7 | 2·4 |
| RS130 .. | ,, | 9·7 | 0·5 | 5·1 |
| RS187 .. | ,, | 7·6 | Nil | 0·7 |
| Triploid Means .. | | 6·8 | 0·4 | 4·0 |

To investigate the possibility that this condition might apply to triploid cones, samples were collected in 1956, from a series of triploids raised from both Bullion and Fuggle N. In the case of the Bullion triploids, these were first year plants raised from cuttings taken from original seedling material, and each sample consisted of 50 cones. The Fuggle triploids were seedlings in their first year, and individual crops were small, in some cases the total yield was less than the desired 50 cones. Samples were picked from diploid plants of both varieties, comparable in size and vigour to the triploids, to serve as controls; a sample was also picked from a tetraploid Bullion plant as a further control for that variety.

On analysis, the cones from each sample were carefully dissected and the numbers of bracts, bracteoles and seeds for each cone were recorded.

The results, given in Table 2, show that as far as numbers of bracts and bracteoles are concerned, the triploid cones showed close similarity to those from the diploids. In the case of the

Bullion series, the same similarity is apparent between the triploids and the tetraploid form from which they were directly raised. It is clear that lower seed content in triploids is not a result of a lower number of bracteoles.

Table 2

Results of Petal Counts of Diploids and Polyploids

Bullion Series

| Sample | Ploidy | Number of cones | Average per cone | | |
|---|---|---|---|---|---|
| | | | Bracts | Bracteoles | Seeds |
| Bullion .. | 2x | 50 | 23·9 | 41·7 | 16·9 |
| Bullion .. | 4x | ,, | 25·3 | 44·6 | 20·7 |
| WFR5 .. | 3x | ,, | 22·4 | 40·0 | 2·9 |
| WFR8 .. | ,, | ,, | 24·4 | 43·7 | 3·1 |
| WFR14 .. | ,, | ,, | 21·5 | 36·2 | 0·9 |
| WFR15 .. | ,, | ,, | 24·2 | 40·7 | 0·5 |
| WFS22 .. | ,, | ,, | 26·2 | 47·6 | 3·7 |
| WFT2 .. | ,, | ,, | 23·2 | 40·1 | 1·1 |
| WFT10 .. | ,, | ,, | 23·3 | 40·7 | 1·9 |
| WFT14 .. | ,, | ,, | 28·3 | 50·2 | 2·6 |
| Triploid Means .. | | | 24·2 | 42·4 | 2·1 |

Fuggle Series

| Sample | Ploidy | Number of cones | Average per cone | | |
|---|---|---|---|---|---|
| | | | Bracts | Bracteoles | Seeds |
| Fuggle .. | 2x | 17 | 14·6 | 21·4 | 8·0 |
| RP96 .. | 3x | 50 | 13·9 | 21·9 | 0·4 |
| RQ52 .. | ,, | ,, | 14·1 | 23·7 | 0·04 |
| RR38 .. | ,, | ,, | 14·9 | 24·4 | 0·5 |
| RR66 .. | ,, | ,, | 18·5 | 31·4 | 0·4 |
| RR83 .. | ,, | 20 | 15·3 | 25·0 | 0·2 |
| RR103 .. | ,, | 23 | 17·0 | 28·9 | 0·9 |
| RS130 .. | ,, | 50 | 16·2 | 26·7 | 0·5 |
| RS187 .. | ,, | ,, | 14·1 | 23·2 | Nil |
| Triploid Means .. | | | 15·5 | 25·7 | 0·4 |

A Commercial Method of Seed Assessment and its Application to Triploids

Any triploid which may be accepted into general hop growing, will need to be carefully assessed for seed content. This could be an important factor to be taken into account when valuations are carried out. At the present, all hops harvested in this country are treated as seeded, and relative seed contents have little or no effect on valuation. On the Continent, where hops are grown seedless by the elimination of male plants, a directly opposite situation maintains, all hops being classed as seedless.

In the U.S.A., however, both seeded and unseeded hops are produced, and a technique is employed to determine the seed contents. This technique, reported by the Hop Industry Productivity Team (1951) is similar to that described by Burgess (1925) and is based on the further drying of a 20 gm. sample of kiln dried hops to a point where the resin is no longer sticky. The petals can then be rubbed to a fine powder between the palms of the hands and the seed recovered by a system of sieving and shaking. The seeds are weighed to the nearest 0·01 gm. and the result $\times 5$ is taken as the percentage of seed.

In much of the work carried out on triploids at Wye, seed has been carefully picked out by hand from samples of kiln-dried cones, every bracteole being inspected individually. In view of the considerable amount of work involved, it was decided to look into the possibility of using the American method in the future.

This investigation was divided into two phases, the first being to ensure that the American technique was being used correctly. A series of packs of seeded and unseeded cones from the 1957 American crop were dealt with, each pack having marked on its label the seed content of the bales it represented. A 20 gm. sample was taken from each pack, and the seed recovered by the re-drying method. The figures given in Table 3 show the stated seed contents and those obtained at Wye.

The similarity of the results indicated that no great error in the employment of the method was likely to arise, and the second phase was carried out. This was a direct comparison between the American and Wye methods on two series of samples of the same variety. Normally seeded Northern Brewer was selected, and five samples of 10 gm. each, and five samples of 20 gm. each were taken. The five 10 gm. samples were analysed for seed by the Wye method, 10 gm. being the weight used in all previous seed content analyses. The five 20 gm. samples were analysed by the American method.

Table 3
Results of Analyses by American Method on Samples of Stated Seed Content

| Variety | % seed weight as on label | % seed weight by analysis at Wye |
|---|---|---|
| Yakima seedless lates .. | 0 | 1·7 |
| ,, ,, ,, .. | 0 | 0·2 |
| ,, ,, earlies .. | 0 | 0·4 |
| ,, ,, ,, .. | 0 | 0·1 |
| ,, seeded lates .. | 4 | 4·8 |
| ,, ,, earlies .. | 4 | 4·9 |
| ,, ,, ,, .. | 6 | 7·1 |
| ,, ,, lates .. | >6 | 6·4 |

From the results given in Table 4, it was apparent that in those samples analysed by the American method, a lower seed weight was largely accounted for by a loss of seed. The difference

Table 4
Seed Contents of Samples of Northern Brewer as Analysed by Wye and American Techniques

| Sample | Number of Seeds per sample | Av. number of seeds per gm. of sample | Weight of seed % |
|---|---|---|---|
| | 10 gm. samples. Wye Method | | |
| 1 | 615 | 61·5 | 16·8 |
| 2 | 652 | 65·2 | 18·4 |
| 3 | 505 | 50·5 | 15·9 |
| 4 | 581 | 58·1 | 17·6 |
| 5 | 546 | 54·6 | 16·4 |
| Means | 580 | 58·0 | 17·0 |
| | 20 gm. samples. American Method | | |
| 1 | 988 | 49·4 | 13·7 |
| 2 | 850 | 42·5 | 12·9 |
| 3 | 968 | 48·4 | 13·9 |
| 4 | 961 | 48·1 | 12·8 |
| 5 | 939 | 47·0 | 13·4 |
| Means | 941 | 47·1 | 13·3 |

of over 3 per cent. against the figures for the Wye method, represents a loss of about one-fifth of the seed weight in this instance.

It was considered likely that the seeds lost from a sample analysed by the American method, would prove to be hollow. Careful examination of a sample during the powdering process, showed this to be so; many broken seed cases could be found, but none contained an embryo.

It was recorded in the earlier work, that triploid cones contain a high proportion of hollow seeds. To find out how this would affect the difference between results from the two methods of analysis, samples of 20 gm. each from seven Fuggle triploids and two Fuggle controls, were analysed by both methods. By using the Wye method first it was possible to return the seed recovered from each sample, to the petal, and then analyse each sample again by the American method.

The results shown in Table 5 clearly illustrate that the difference between the seed content figures obtained by the two methods, is much greater in the triploids than in the diploids. The differences,

TABLE 5

RESULTS FROM 20 GM. SAMPLES ANALYSED FIRST BY THE WYE METHOD, THEN WITH SEED RECOMBINED WITH THE PETAL, ANALYSED BY THE AMERICAN METHOD

| Variety | Ploidy | Wye Method | | American Method | | | |
|---|---|---|---|---|---|---|---|
| | | Number of seeds | Weight of seeds (gm.) | Number of seeds | % drop in seeds numbers | Weight of seeds (gm.) | % drop in seed weight |
| Fuggle | 2x | 1,567 | 4·82 | 1,559 | 0·5 | 4·21 | 12·7 |
| Fuggle | ,, | 1,568 | 4·82 | 1,433 | 8·6 | 4·12 | 14·5 |
| Diploid Means | | 1,568 | 4·82 | 1,496 | 4·6 | 4·17 | 13·6 |
| RP96 | 3x | 681 | 1·02 | 387 | 43·2 | 0·59 | 42·2 |
| RQ52 | ,, | 784 | 1·11 | 446 | 43·1 | 0·62 | 44·1 |
| RR66 | ,, | 772 | 1·08 | 405 | 47·5 | 0·57 | 47·2 |
| RR83 | ,, | 521 | 0·67 | 272 | 47·8 | 0·36 | 46·3 |
| RR103 | ,, | 321 | 0·47 | 221 | 31·2 | 0·29 | 38·3 |
| RS130 | ,, | 560 | 1·01 | 461 | 17·7 | 0·62 | 38·6 |
| RS187 | ,, | 100 | 0·14 | 91 | 9·0 | 0·09 | 35·7 |
| Triploid Means | | 534 | 0·79 | 326 | 34·2 | 0·45 | 41·8 |

expressed as percentages of the results from the Wye method, give some measure of the greater proportion of hollow seeds which are produced by the triploids.

If it is accepted that hollow seeds are lighter than sound ones, then the percentage drop in seed weight should be less than in seed number. The fact that this is not always the case is due to a loss in weight, of the seeds recovered by the American method, as a result of the re-drying process. In the Fuggle samples, the drop in seed number was small, therefore the drop in seed weight was largely due to re-drying. The triploid samples on the other hand, with their higher proportion of hollow seed, have a higher percentage drop in seed weight, and this tends to mask the effect of the loss due to re-drying.

The American method of analysis can be considered satisfactory for comparing the sound seed content of hop samples. For investigations where the content of both sound and hollow seeds is required, samples must be analysed by a method which does not destroy the latter.

### Seed Content of Continental "Seedless" Hops Compared with Triploids

The production of seedless hops on the Continent has been developed by the elimination of male plants, and the crop commands a high price in world markets. The elimination of male hop plants in this country would raise many problems; at the moment such a course would be impracticable, and as far as can be seen would not be generally desired.

To determine the accuracy of the general statement that continental hops are seedless, and to see how triploids may stand in relation to them, samples were taken from 14 packs of the 1957 continental crop. These samples, each of 20 gm. weight, were analysed by the American method. As shown in Table 6, seeds were found in 12 of the samples, but in 8 of these the amounts were very small. The presence of any seed, however, seems to indicate that some male hop plants still exist in the continental hop-growing areas.

When the results are considered in relation to those from triploid samples analysed by the same method, it must be accepted that triploids will be unlikely to have a seed content quite as low as the best continental hops.

TABLE 6

RESULTS OF SEED ANALYSES ON 20 GM. SAMPLES OF CONTINENTAL HOPS (1957 CROP)

| Variety* | Country where grown | Number of seeds | Weight of seed (gm.) |
|---|---|---|---|
| Hallertau | Belgium | 71 | 0·18 |
| Saaz | Czechoslovakia | 24 | 0·02 |
| ,, | ,, | 5 | — |
| ,, | ,, | 5 | — |
| Ustek | ,, | 27 | 0·02 |
| Alsace (Spalt) | France | 30 | 0·06 |
| Hallertau | Germany | 4 | — |
| Hersbruck Gebirg | ,, | 4 | — |
| Jura | ,, | 0 | — |
| Spalt | ,, | 7 | — |
| Tettnang | ,, | 3 | — |
| Batschkaer | Yugoslavia | 7 | — |
| Styrian | ,, | 0 | — |
| ,, | ,, | 5 | — |

* Varieties on the Continent are generally given the name of the district where they were first grown.

## GENERAL DISCUSSION

The problem of producing a hop variety with the qualities required by both grower and brewer, can only be solved by breeding and selection. The use of polyploidy shows promise of reducing many of the difficulties encountered in a breeding programme, but certain characteristics of triploids, while appearing advantageous, may raise a new set of problems.

It has been shown that the cones produced by triploids are normal in structure, but differ from diploids in that they have a lower seed content. This is accompanied by a degree of resistance to shattering which will undoubtedly prove an advantage in machine picking. The toughness of triploid cones was again noted during the analyses carried out in 1956 and 1957.

Should a triploid produce a crop comparable in bulk to that from a diploid, by virtue of its lower seed content it would weigh less. A brewer receiving a pocket of such hops would be buying less unwanted seed but at least as much useable hop material, and the price of such a pocket, based on weight, would not represent its true value.

It has been shown by Neve (this report, page 43), that the mean value for resin content of Fuggle triploids, approximates to that of Fuggle, when allowance is made for the difference in seed

content. Without such an allowance being made, triploids show a a higher resin content when analysed on a weight basis, although the yield of resin per acre may be the same. This means that before a grower of triploids could expect a fair price for the resin per acre he has produced, a higher scale of valuations would have to be introduced.

Unless the seed content of triploid varieties is found to be largely unaffected by environmental conditions, some form of commercial seed assessment will be necessary. The American technique described would appear to be satisfactory, particularly if it can be established that brewers' objections to seed in hops does not apply to hollow cases.

The demand for an English hop suitable for lager brewing, suggests an important field for triploid development. Whether or not a triploid of satisfactory aroma could be a suitable replacement for continental seedless varieties, depends upon the opinion of brewers as to how much seed they will tolerate. Lager brewers, and others who use imported "seedless" hops, generally state that they want no seed at all. That the presence of seed has been shown in continental samples, means that brewers must be tolerating a low seed rate in some of their imported hops. It remains to be seen what level of seed constitutes a real disadvantage to the brewer of lager beer. Meanwhile, investigations will continue into the possible use of triploid hops in the industry at large.

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# SOME NEW VARIETIES OF HOPS IN WYE FIELD PLOTS

## A FINAL REPORT

F. H. Beard

Summary

The grubbing of Wye Field hop garden through Progressive Wilt has ended a series of trials with new seedling hop varieties raised by Professor E. S. Salmon. The opportunity is taken to present the data available for 42 such seedlings.

Information on all 42 varieties is summarized in tabular form in respect of parentage, yield, physical appraisal, resin analysis (P.V.), cultural details and resistance or susceptibility to diseases. Eight of the varieties are considered to be of interest and are discussed in fuller detail; these are WFB26, OQ14, WFB145, WFG66, WFH65, AA70, OZ97*a* and X111. The last two are tolerant to Progressive Wilt.

### Introduction

The abandonment of Wye Field hop garden at Wye College owing to Progressive Wilt brings to an end the field trials carried out there with the more promising of the large number of seedling hops raised by Professor Salmon. From 1917 to 1950 the trials were carried out at East Malling Research Station and reports on these trials have been published (Salmon, 1918-49). Though a number of seedling varieties were planted out in the Wye Field plots prior to 1950, no systematic records had been made of their performance. In 1950 these variety trial plots were extended to include selected seedling varieties from the East Malling collection and also some, as yet, untested seedlings. In 1955 a detailed report on 33 varieties was published (Beard and Salmon, 1955). The present report covers a further 33 varieties together with nine seedlings mentioned in the 1955 report, but of which only limited records were then available.

An account of the general lay-out and management of the variety trial plots has already been given (Beard and Salmon, *loc. cit.*) and will not be repeated here. However, it is necessary to state again that the close plant (6 ft. square) and low wirework (12 ft. 9 in.) adversely affect the performance of the very vigorous varieties even when only a single bine is trained up each string.

PARENTAGE OF VARIETIES

The 42 varieties discussed in this paper may be grouped into six main lines of descent as follows:

1. Eight descendants from an original cross between Canterbury Golding and male OB21; this male being derived from the variety Brewer's Gold (C9*a*) introduced Manitoba genes. These eight varieties comprise three seedlings of the first generation, sister varieties of Northern Brewer (WFB135), and five seedlings of the second generation derived from open pollination at Wye; three from Wye Field Golding (WFC81), and two from John Ford (WFA90).

2. Fourteen descendants from the Wild Manitoba hop, BB1, by open pollination at Wye. This group comprises:

(*a*) two varieties of the first generation, sister varieties of Brewer's Gold (C9*a*) and Bullion (Q43);

(*b*) eight seedlings of the second generation, three from Bullion (Q43), four from Brewer's Gold (C9*a*) and one from OL43;

(*c*) four seedlings of the third generation; two from progeny of Brewer's Gold, and one each from Bullion and Nonsuch (OB53).

3. Seven descendants of the New Mexican hop (*H. americanus* var. *neo-mexicanus*) by open pollination at Wye. Of these, two are of the first generation, two of the second generation, and three of the third generation.

4. Three descendants of the American variety Oregon Cluster by open pollination at Wye, two being of the third generation, and one of the fourth generation.

5. Four varieties derived from the open pollination of the Fuggle variety at Wye.

6. Two varieties derived from the Bramling, one a cross with a male seedling of the Manitoba Wild Hop, and one a cross with a male seedling of the New Mexican Hop.

In addition there are four varieties that do not fall into any of these groups. Two of these are second generation seedlings of B20, a Golding hop of unknown origin found growing at Wye at the time Professor Salmon started his breeding work. The other two varieties are a second generation seedling from a cross between

the ornamental Golden Hop and an Oregon male; and a seedling of a Late Bavarian hop.

### Presentation of Summarized Data

Information on each variety is summarized in Tables 1-12 below under the following headings:

(*a*) Yield in cwt. of dried hops per acre.

(*b*) Physical (organoleptic) examination: commercial appraisal of the appearance and aroma of the dried sample.

(*c*) Chemical analysis for soft resin content (preservative value).

(*d*) Cultural details.

(*e*) Susceptibility to Downy Mildew and other diseases.

In the tables the data on mean yields and mean resin content are accompanied by numbers in brackets which indicate the number of seasons from which the average is derived. In some cases yield data are only available for a few seasons at Wye but in such cases if East Malling data for a longer period is available it is also given.

No information is given as to the relative susceptibility of the varieties to Downy Mildew attack on the cones. Such information would be misleading as the incidence of cone infection may be affected by such factors as amount of bine growth, stage of growth when the protective copper sprays are applied, and by the time of picking. In a garden containing varieties of all seasons planted at random it is impossible to apply sprays at the optimum time for each. Detailed records have been made each season on the number of Downy Mildew spikes and a report on this has recently been published (Beard, 1957). Rootstock infection is assessed by the number of hills that have died or have been recorded as weak, Downy Mildew being the commonest cause of dead and weak hills.

It may be noted that there appears to be an increasing tendency towards rootstock injury in the seedlings selected by Professor Salmon in later years. Of the 42 varieties discussed in this report, no less than 28 have suffered from this trouble to a greater or lesser extent.

### Fuller Details on Eight Varieties

Of the 42 seedlings listed above in the tables, eight are considered to be of some interest and are discussed in more detail below. These further data are given for each seedling in note form under the same headings as used in the tables.

TABLE I.

CANTERBURY GOLDING × OB21 (SEEDLING OF BREWER'S GOLD)—FIRST GENERATION

| Variety and plot number | (a) Mean yield per acre in dried cwt. | (b) Physical examination | (c) Mean resin analysis % alpha | % beta | (d) Cultural details | (e) Downy mildew and other diseases |
|---|---|---|---|---|---|---|
| WFH6* (10) | 19·95 (2) | Weak, rather disappointing aroma | 5·18 | 10·53 (1) | Moderate vigour; fruitful; nice cones. Late | Moderate incidence of spikes; liable to rootstock injury |
| WFB26 (36) | 15·23 (3) | Pleasant, English type aroma; good appearance | 6·02 | 9·16 (4) | Weakish grower, short laterals, large solid cones. Midseason | Resistant to spike form of Downy Mildew, but liable to rootstock injury |
| WFI66* (37) | 23·23 (4) | Pleasant, English type aroma | 4·92 | 10·61 (3) | Vigorous and croppy; tendency for leafy cones in some seasons. Midseason—late | Moderate or light incidence of spikes. Susceptible to mould |

* Included in 1954 report.

TABLE 2

CANTERBURY GOLDING=OB21 (SEEDLING OF BREWER'S GOLD)—SECOND GENERATION
(A) via Wye Field Golding (WFC81). (B) via John Ford (WFA90)

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| OQ14* (A) (8) | 22·83 (4) | Pleasant, Golding type aroma | 6·83 10·75 (3) | Vigorous grower, but is very late in starting growth if weather remains cool. In some seasons this may affect cropping to a serious extent. Late | Entirely free from basal spikes, but liable to have moderate number of lateral spikes in years favouring this type of infection |
| WFB4 (A) (23) | 25·65 (1) | Pungent aroma; poor rub | 8·98 8·78 (1) | Weak grower, but many smallish cones. Mid-season—late | Low incidence of spikes, but very liable to rootstock injury |
| WFB145 (A) (42) | 23·51 (1) | Pleasant, mild aroma ?Golding | 9·02 8·83 (1) | An attractive hop, worthy of further trial (planted 1955). Midseason—late | Low incidence of spikes; no rootstock injury to date |
| WFF90 (B) | 19·74 (4) | Pleasant English type aroma, possibly Golding | 7·22 9–18 (2) | Fine, short jointed bine, hopping well down, with attractive pale cones; irregular cropper. Mid-season | Moderate number of basal spikes, fairly numerous lateral spikes with a higher than usual proportion of terminal spikes; considerable rootstock injury in 1956 and '57 (planted 1951 and '52) |
| DD16 (B) (49) | — | Pleasant, possibly Golding type aroma | 8·02 8·78 (1) | Hills uneven, many weak with scanty bine. Late | Moderate number of spikes: liable to rootstock injury |

* Included in 1954 report.

TABLE 3

FIRST GENERATION FROM WILD HOP, MANITOBA (BB1)

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| X69 (57) | 22·42 (3)<br>20·14*(8) | Good appearance, coarse aroma (American) | 5·61 9·35 (2)<br>6·45* 10·34*(4) | Very vigorous (similar to Brewer's Gold). Only one bine to a string and ample room required. Produces some male flowers in certain seasons. Late—very late | Few basal spikes; hardly any lateral spikes and no terminal spikes. Hills may sometimes be weakened but are not killed. |
| OA59 (73) | 24·98 (2)<br>22·18*(14) | Strong, unpleasant American aroma | 4·10 13·36 (3)<br>4·69* 13·33*(5) | Very vigorous (similar to Brewer's Gold). Only one bine per string and ample room required. Late | Low incidence of spikes; no evidence of rootstock injury |

* East Malling data.

TABLE 4

SECOND GENERATION FROM WILD HOP, MANITOBA (BB1)

(A) via Bullion (Q43). (B) via Brewer's Gold. (B1) Brewer's Gold × Russian Male. (C) via OL43.

| Variety and plot number | (a) | (b) | (c) | (d) | (e) |
|---|---|---|---|---|---|
| WFG66* (A) (7) | 21·01 (4) | Good appearance, very strong, coarse aroma which is not definitely American | 6·89 15·55 (3) | Very vigorous, needs high wirework, laterals long and cones borne rather singly ; cones large and pointed. Would be a poor cropper except for its good bushel/cwt. ratio (88). Late | Very low incidence of spikes, no rootstock injury |
| WFH65* (A) (61) | 24·96 (5) | Good appearance, "fruity" aroma, sometimes considered unpleasant | 5·01 11·59 (3) | Moderate vigour, little head, but long ropes of hops, nice pale green cones; a thoroughly attractive hop from the growers' viewpoint; resists wind damage. Mid-season—late | Very low incidence of spikes, no rootstock injury |
| AA70 (A) (78) | 21·16 (2) | Good—very good appearance; aroma variable; sometimes not liked | 6·34 12·76 (2) | Moderate vigour ; hills often rather variable, tendency for bare lower bine on some hills. Mid-season—late | Very low incidence of spikes, but evidence of light rootstock injury. |

* Included in 1954 report.

TABLE 4—*continued*

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| AOM12 (B) (53) | 18·52 (1) | Fair appearance, unattractive aroma | 10·45 11·23 (1) | Generally poor, with scanty bine. Late | Low incidence of basal spikes, moderate lateral and terminal spikes; liable to rootstock injury |
| OT100 (B) (77B) | 17·88 (2) | Good appearance, aroma doubtful | 5·19 13·36 (2) | Moderate vigour with croppy hills in earlier years (planted 1950-51) but becoming weak and uneven in later years. Late | Light—moderate incidence of spikes; severe rootstock injury |
| ADD4 (B) (80) | 21·33 (2) 14·97† (5) | Aroma pleasant, but weak and lacking in character | 5·20 9·03 (3) | Good hills vigorous and croppy, but many weak and uneven hills. Did poorly on light Malling loam. Late | Very low incidence of spikes but severe rootstock injury |
| CC23 (B1) (12) | 10·50 (2) | Very good appearance; very pleasant aroma perhaps resembling an Oregon Fuggle | 6·82 12·05 (1) | Untidy, straggly, growth; hills weak and uneven; bine scanty; nice pale Manitoba-type cones. Midseason—late | Very low incidence of spikes, but liable to rootstock injury |
| 94*a* (C) (3) | 18·56 (1) | Pleasant ; fragrant aroma; good appearance | 7·84 8·82 (3) | Weak grower with scanty bine; nice pale cones. Midseason—late | Few—moderate basal spikes; moderate—many lateral and terminal spikes, severe rootstock injury |

† East Malling data.

TABLE 5

THIRD GENERATION FROM WILD HOP, MANITOBA (BB1)

(A) via Brewer's Gold (C9*a*) and AEE44. (B) via 334*a* and Nonsuch (OB53). (C) via Brewer's Gold (C9*a*) and II149

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| OB6 (A) (5) | 21·16 (2) | Variable opinions as to aroma | 6·05 11·16 (2) | Vigorous, croppy; cones small, but well formed. Late—very late | Almost free from basal spikes and entirely free from terminal spikes, but very liable to lateral spikes. Subject to attack by *Verticillium dahliae* wilt. A few weak and dead hills have been recorded and may have been due to either Downy Mildew or *V. dahliae* |
| WFD88* (B) (32) | 21·90 (4) | Variable opinions as to aroma | 6·76 11·07 (4) | Moderate vigour, but croppy; cones large and borne rather singly. Midseason | Light—moderate incidence of basal and terminal spikes; relatively high incidence of terminal spikes, very liable to rootstock injury |
| FF59 (B) (50) | 27·29 (1) | Good appearance American aroma, unpleasant | 6·62 8·77 (2) | Very vigorous in early years (planted 1950 and 1951), but weak and uneven in 1956 and 1957. Very late | Moderate incidence of basal spikes, very few lateral spikes and no terminal spikes; severe rootstock injury. Suspectible to mould |
| OW131 (C) (82) | 24·16 (1) | Very weak, American aroma | 5·64 14·60 (2) | Crop mainly on heads, tails rather poor; small dense cones | Freedom from basal spikes and very low incidence of lateral and terminal spikes; liable to rootstock injury |

* Included in 1954 report.

TABLE 6

SEEDLINGS OF NEW MEXICAN HOP (*H. americanus* var. *neomexicanus*)

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| AOV52 (22) | 26·62 (2) | Strong American aroma, good appearance | 4·52 9·55 (2) | Very vigorous, needs ample room and only one bine per string; extremely late in season | Very low incidence of spikes; may be slightly subject to rootstock injury |
| OZ97*a* (45) | 26·23 (2) | American aroma; good appearance | 6·88 12·29 (4) | Very vigorous; one bine per string and adequate room needed; large, rather soft pale green cones. Late | Low incidence of basal spikes, but moderate—high incidence of lateral spikes in some seasons; no rootstock injury. Tolerant of *Verticillium wilt*, being equal to Keyworth's Midseason (OR55). |

TABLE 7

SECOND GENERATION FROM NEW MEXICAN HOP (via Y90)

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| X111 (26) | 17·30 (2) | American aroma, sometimes considered unpleasant | 7·50 8·94 (2) | Vigorous, dark green leaves and pale, rather soft cones; an irregular cropper. Late | Very low incidence of spikes; no evidence of rootstock injury. Wilt-tolerant |
| OM17 (38) | 22·33 (3)<br>15·91* (6) | Good appearance, aroma not attractive, though not American | 7·17 9·29 (2) | Vigorous, tails rather bare; nice well developed, pale cones, did poorly on light Malling loam. Mid-season—late | Very low incidence of spikes; no evidence of rootstock injury |

* East Malling data.

TABLE 8

THIRD GENERATION FROM NEW MEXICAN HOP
(A) via Y90 and R1/94. (B) via Y90 and EE92

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| AOR43* (A) (46) | 22·97 (4) | Unattractive aroma | 7·93 10·11 (2) | Vigorous, long laterals, smallish cones. Late | Moderate number of basal spikes; few lateral and terminal spikes, no evidence of rootstock infection |
| OL42 (B) (74) | 24·06 (3) | Strong American aroma ; good appearance | 6·28 9·54 (2) | Vigorous and croppy in early years, but poor, weak and uneven in 1956 and 1957 (planted 1950 and 1951); good well developed cones, borne rather singly. Late | Heavy incidence of spikes, particularly basal, having the highest number of any Wye Field plot. Liable to rootstock injury |
| AOP6 (B) (85) | 24·95 (1) 17·47†(3) | American aroma | 5·09 7·52 (2) | Crops well down bine, well developed cones. Mid-season—late | Very low incidence of spikes; evidence of rootstock injury; very liable to attacks of Mould |

* Included in 1954 report. † East Malling data.

TABLE 9

SEEDLINGS DERIVED FROM THE OREGON CLUSTER

(A) third generation, via M45 and OQ17. (B) fourth generation via M45, OP13 and L11

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| EE14 (A) (19) | 23·02 (1) | Mild, non-American aroma | 6·13 12·44 (1) | Vigorous in early years (planted 1950 and 1951) with long untidy laterals, generally poor, weak and uneven from 1955 onwards; Golding-type cones. Late | High incidence of basal spikes, low—moderate incidence of lateral spikes; considerable rootstock injury |
| HH50 (A) (83) | 15·91 (4) | Good appearance, mild American aroma | 7·38 11·65 (3) | Weak and poor, unattractive straggly growth. Late | Light or moderate incidence of spikes; very considerable rootstock injury |
| ACCC5 (B) (69) | 15·40 (2) 16·48*(7) | Poor appearance, unpleasant aroma | 2·49 12·41 (2) | Weakish grower, but masses of hops on whole length of bine, no heads; long, thin cones. Early —midseason | Moderate incidence of basal spikes, heavy incidence of lateral and terminal spikes; no indication of rootstock injury |

* East Malling data.

TABLE 10

SEEDLINGS OF FUGGLE

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| OV125 (27) | 21·16 (2) | Weak, indifferent aroma | 6·86 9·04 (2) | Uneven hills, weakish; nice pale well developed cones. Midseason | Moderate—many spikes; liable to rootstock injury |
| R20 (31) | 21·61 (2) | Variable reports on aroma | 4·93 9·67 (2) | Vigorous. Late | Absence of basal spikes and very few lateral and terminal spikes; no indication of rootstock injury |
| DD57 (47) | 19·71 (2) | Variable reports on aroma ; good appearance | 4·45 11·40 (4) | Vigorous in early years, and then gradually becoming weak and uneven. Midseason—late | Basal spikes very numerous, moderate incidence of lateral and terminal spikes; subject to rootstock injury |
| OR47 (56) | 21·12 (2) | Poor appearance and aroma | 4·42 8·04 (2) | Vigorous, lower bine rather bare, small cones. Midseason | Basal spikes very numerous ; light — moderate incidence of lateral and terminal spikes; no evidence of rootstock injury |

TABLE 11

SEEDLINGS OF BRAMLING

(A) crossed with male seedling of Manitoba Wild Hop. (B) crossed with male seedling of New Mexican Hop

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| OW92 (A) (29) | 24·95 (2) | Very good appearance; pleasant aroma | 5·60 10·19 (3) | Vigorous and croppy; crops well down bine; cropped poorly on light Malling loam. Mid-season—late | High incidence of basal spikes, low—moderate incidence of lateral and terminal spikes; subject to rootstock injury |
| DD12 (B) (65) | 23·32 (2) 15·21*(3) | Good appearance, pleasant English aroma | 7·31 10·95 (4) | Generally vigorous and croppy, apart from some weak hills; cones small; did poorly on light Malling loam. Late | Moderate incidence of spikes, with tendency for higher proportion of basal spikes; subject to rootstock injury. |

* East Malling data.

TABLE 12

SEEDLINGS OF VARIOUS (UNCLASSIFIED) ORIGINS

(A) seedlings of OL99 (seedling of B20, a Golding type hop of unknown origin).
(B) seedling of Z100 (Bides Golden hop × Oregon male). (C) seedling of Late Bavarian hop.

| Variety and plot number | (*a*) | (*b*) | (*c*) | (*d*) | (*e*) |
|---|---|---|---|---|---|
| EE64 (A) (4) | 18·64 (1) 16·25*(4) | Good appearance, pleasant, sweet and mild aroma | 5·11 7·89 (1) | Weak—moderate vigour; scorching of lower leaves in some seasons. Golding-type cones. Midseason | Very low incidence of basal spikes; moderate—high incidence of lateral spikes; some evidence of hills weakened but no deaths recorded; only planted 1953 |
| OT22 (A) (43) | 23·83 (2) 14·82*(4) | Good appearance, pleasant aroma | 5·48 9·63 (5) | Vigorous and croppy in early years, uneven in later years. Nice small cones; did poorly on light Malling loam. Midseason—late | Very low incidence of basal and lateral spikes, complete freedom from terminal spikes; liable to rootstock injury |
| K31 (B) (70) | 18·33 (3) 14·53*(4) | Good appearance, Bullion-type aroma | 5·26 9·56 (1) | Unattractive, straggly type of growth with rather bare laterals; small Golding-type cones. Midseason—late | Light—moderate incidence of spikes; liable to rootstock injury |
| OY43 (C) (33) | 23·85 (2) 18·01*(6) | Weak, but unpleasant aroma | 5·99 10·15 (4) | Uneven, but best hills vigorous and croppy; cones small with few petals. Late | Moderate incidence of basal spikes; high incidence of lateral and terminal spikes; liable to rootstock injury |

* East Malling data.

WFB26. First generation seedling of Canterbury Golding crossed with OB21 (Table 1). Plot 36: planted 1953-55.

(*a*) 1950: 15·74 cwt. per acre (plots 4, 6 and 26).

(*b*) 1938: "Good Golding appearance; pleasant English aroma, but more like a Fuggle than a Golding; of commercial promise" (Merchant).
1945: "I cannot detect American aroma; they are like high quality English; they will replace Goldings but could do with more resins" (Brewer).
1947: "Good appearance, silky; rich 'round' Golding aroma" (Merchant).

(*c*) 1938: ( 8.11.38) 6·86% alpha resins, 9·81% beta resins.
1945: (11.12.45) 5·82% alpha resins, 9·13% beta resins.
1949: (16.2.50) 5·80% alpha resins.
1950: ( 7.2.51) 5·58% alpha resins, 8·54% beta resins.

(*d*) This variety was originally planted in plots 4, 6 and 26, but certain hills showed symptoms of mosaic (virus) disease. As tests showed that the parent hill of WFB26 was a tolerant carrier of mosaic it was considered that the stock had become mixed, probably with Southern Brewer (WFA111) a known mosaic-susceptible. The great similarity of the varieties in this group makes roguing difficult, so that it was decided to plant a new plot (36) with unmixed material.
1938 (nursery row): "Heavy crop, easy to pick; rich large solid cones."
Plot 36: weak—moderate vigour, short laterals becoming dense, masses of cones. In 1957 the plot was recorded as generally weak, uneven and poor. Midseason.

(*e*) Mean annual number of spikes per 100 hills: 73 basal, 19 lateral, 4 terminal.
Evidence of rootstock injury; 3 weak hills were recorded and 4 deaths occurred.

OQ14. Second generation seedling from Canterbury Golding by open pollination of Wye Field Golding (WFC81) (Table 2). Plot 8: planted 1950-51.

(*a*) 1953: 25·47 cwt. per acre. 1954: 20·58 cwt. per acre.
1955: 30·87 cwt. per acre. 1957: 14·39 cwt. per acre.

(*b*) 1952: "Appearance good; small cones and 'bitty'; aroma very good, like Golding" (Brewer).
1953: "Appearance very good; aroma pleasant, trace of ester; aroma is English" (Brewer).
1954: "Appearance fair, slightly burnt appearance; aroma pleasant, mild; good Golding-type aroma" (Brewer).
1955: "Mild pleasant aroma with slight Golding character" (Merchant).

(*c*) 1952: ( 5.1.53) 7·52% alpha resins, 11·42% beta resins.
1953: (11.1.54) 6·14% alpha resins, 11·26% beta resins.
1954: ( 6.12.54) 6·83% alpha resins, 9·57% beta resins.

(*d*) Bine green, cones rather small but very dense. This variety is extremely slow in starting into growth so that it is quite usual to find in May (when the bines of most varieties are about 2 ft. high) that it is only just commencing growth. In most seasons the growth quickly catches up with other varieties so that by the end of the season there is ample bine. However, in 1957 it was found that, when the early part of the summer remains cool, growth is so delayed that the crop is greatly reduced and what there is, is so late that there is no chance of it ripening before the end of the season. For this reason, though it has been grown for some while on a small commercial scale, it cannot now be recommended for general cultivation. Under conditions of commercial practice, this variety has proved difficult to train.

(*e*) There is definite resistance to Downy Mildew. Mean annual number of spikes per 100 hills: 0 basal, 59 lateral, 5 terminal. There has been no evidence of rootstock injury.

WFB145. Second generation seedling from Canterbury Golding by open pollination of Wye Field Golding (WFC81) (Table 2). Plot 42: planted 1955.

(*a*) 1957: 23·51 cwt. per acre.

(*b*) 1953 (box sample): "Appearance fair, raw green; fair rub; very pleasant mild aroma; we hesitate to go as far as saying 'Golding' " (Merchant).

(*c*) 1953: 9·02% alpha resins, 8·83% beta resins.

(*d*) 1953 (nursery row): "Croppy, long, thin, pointed cones, thin strig, easy to pick, long laterals." Midseason—late.

This is a very recent planting and appears to be worthy of further trial.

(*e*) Mean annual number of spikes per 100 hills: 5 basal, 150 lateral, 7 terminal. There is no evidence of rootstock injury.

WFG66. Second generation seedling from BB1, Wild Hop, Manitoba, by open pollination of Bullion (Q43) (Table 4). Plot 7: planted 1949.

(*a*) 1953: 24·61 cwt. per acre. 1954: 20·71 cwt. per acre. 1955: 21·92 cwt. per acre. 1957: 16·81 cwt. per acre. This variety would be only a very moderate cropper did it not "weigh" extremely well. The bushel/cwt. ratio has varied from 85-92.

(*b*) 1953: "Appearance very good; aroma pleasant, rich side. The aroma is English with resemblance to Fuggles" (Brewer).
1954: "Aroma pleasant, with rough background" (Brewer).
1955: " Overpoweringly strong fruity aroma, which is not completely unpleasant; good rub and good side" (Merchant).

(*c*) 1947 (17.10.47) : 8.29% alpha resins, 13·33% beta resins.
1953 (12.1.54) : 6·00% alpha resins, 15·70% beta resins.
1954 ( 4.1.55) : 6·38% alpha resins, 17·62% beta resins.

(*d*) The Wye Field spacing and height of wirework are too cramped for this variety, so that all the crop is on the "heads" with barren lower laterals. The large, pointed and very firm cones are borne rather singly on long laterals. It appears that it would be a good hop for machine picking and has a definite appeal to growers interested in "resin per acre." Late in season.

(*e*) Mean annual number of spikes per 100 hills: 5 basal, 28 lateral, 1 terminal. No evidence of rootstock injury.

WFH65: Second generation seedling from BB1, Wild Hop, Manitoba, by open pollination of Bullion (Q43) (Table 4). Plot 61: planted 1949.

(*a*) 1952: 25·39 cwt. per acre. 1953: 26·74 cwt. per acre. 1954: 25·12 cwt. per acre. 1955: 27·82 cwt. per acre. 1957: 19·72 cwt. per acre.

(*b*) 1954: "Appearance good; fresh, slightly fruity aroma, trace of American background" (Brewer).
1955: "Very strong and unpleasant aroma, suggestion of pear drops" (Merchant).
1957: "Very nice appearance, Golding type; aroma unpleasant" (Merchant).

(*c*) 1947 (17.10.47) : 7·54% alpha resins, 12·38% beta resins.
1954 ( 6.12.54) : 3·78% alpha resins, 10·12% beta resins.
1956 (16.1.56) : 3·72% alpha resins, 12·28% beta resins.

(*d*) Moderate vigour, very croppy with little "head", but long "ropes" of hops; cones pale and well developed. There is evidence that the variety has some resistance to wind bruise. If the aroma were more pleasant this would be a very attractive variety.

(*e*) Mean annual number of spikes per 100 hills: 4 basal, 53 lateral, 3 terminal. No evidence of rootstock injury.

AA70. Second generation seedling from BB1, Wild Hop, Manitoba, by open pollination of Bullion (Q43) (Table 4). Plot 78: planted 1953.

(*a*) 1954: 21·83 cwt. per acre. 1955: 20·50 cwt. per acre.

(*b*) 1949 (on box sample): "Excellent appearance, attractive colour, good shine and nice cones; aroma aromatic ester fragrance" (Brewer).
1953 (on box sample): "Appearance very good, a lovely colour, aroma fresh, pleasant fragrance, slightly different from Golding but as good" (Brewer).
1953: "Appearance good; ripe, bold; rub good, aroma strong, not unpleasant, little like onions. Quite a nice hop, but we found the aroma a little like onions" (Merchant).
1954: "Appearance fair, crumbly; aroma strong, esterlike at first then slight roughness; no onion"; later on same sample: "nice fresh aroma, pleasant and faintly like lemon" (Brewer).
1955: "Unpleasant, earthy aroma; not hop-like" (Merchant).

(*c*) 1949: (31.10.49): 6·52% alpha resins, 13·58% beta resins,
1955: (19.12.55) 6·16% alpha resins, 11·94% beta resins.

(*d*) Hills rather variable; good heads, but tendency for lower part of bine to be "blind" and produce no laterals. Nice, firm, pale green cones. Midseason—late.

(*e*) Mean annual number of spikes per 100 hills: 5 basal, 19 lateral, 2 terminal. There is evidence of susceptibility to rootstock injury as two hills were recorded as weak and these have subsequently died.

OZ97*a*: First generation seedling by open pollination from *Humulus americanus* var. *neomexicanus* (Table 6). Plot 45 : planted 1954.

(*a*) 1955: 26·23 cwt. per acre. 1957: 26·23 cwt. per acre.

(*b*) 1939: "Good appearance; powerful aroma, definitely American, but combined with a fruity aroma which I have noted in other samples (varieties) from you, but not, I think, in any commercial sample (variety)" (Brewer).
1953: "Appearance fair, colour patchy, many brown petals; pronounced American aroma; like it better than OR55 (Keyworth's Midseason) but latter has better appearance" (Brewer).
1954: "Appearance very good; aroma pleasant black-currant, strong" (Brewer).
1955: "Mild American aroma of the Brewer's Gold type, but not so pleasant" (Merchant).
1957: "American aroma, milder than Bullion" (Merchant).

(*c*) 1939 ( 6.11.39) : 7·57% alpha resins, 13·12% beta resins.
1953 (14.12.53) : 7·00% alpha resins, 12·10% beta resins.
1954 (17.1.55) : 7·10% alpha resins, 11·60% beta resins.
1955 (16.1.56) : 5·86% alpha resins, 12·34% beta resins.

(*d*) Very vigorous, needs more space and greater height of wirework than in Wye Field; a "one bine per string" variety. Cones large, long, and rather soft, borne somewhat singly. Late—very late in season.

(*e*) Mean annual number of spikes per 100 hills : 13 basal, 683 lateral, 16 terminal. No evidence of rootstock injury. This variety is wilt-tolerant, being equal or rather superior to Keyworth's Midseason.

X111. Second generation seedling from *Humulus americanus* var. *neomexicanus* by open pollination of Y90 (Table 7). Plot 26: planted 1952-53.

(*a*) 1955: 22·42 cwt. per acre. 1957: 12·19 cwt. per acre.

(*b*) 1939: "Moderate appearance, being somewhat weathered; aroma definitely American, but pleasant, so if priced at English average would find buyers. I like it" (Brewer). 1955: "Unpleasant, garlic aroma, poor rub" (Merchant). 1957: "Attractive looking; American aroma" (Merchant).

(*c*) 1939 ( 6.11.39) : 8·22% alpha resins, 9·66% beta resins. 1955 (17.1.56) : 6·77% alpha resins, 8·21% beta resins.

(*d*) Vigorous and needs more space, etc., than in Wye Field, but probably not a "one bine per string" variety. Foliage very dark green; cones pale and rather soft; an irregular cropper; in some years tails are barren, and the cones do not "finish" properly.

(*e*) Mean annual number of spikes per 100 hills : 2 basal, 3 lateral, 0 terminal. No evidence of rootstock injury. This variety shows considerable wilt-tolerance, being superior to Keyworth's Midseason (OR55) and at one time (1947) was grown on a field scale on a "wilt" farm. It was discarded on account of its unacceptable aroma.

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# THE EFFECT OF SPACING AND HEIGHT OF WIREWORK ON THE PATTERN OF GROWTH, YIELD AND RESIN PRODUCTION OF HOPS

F. C. Thompson

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Summary

The mechanization of hop picking has prompted research into methods of growing hops for the machine. Experience in the U.S.A. has indicated that both wider planting and higher wirework encourage the type of growth considered to be most suitable for machine picking—i.e., with the hops evenly distributed along the bine and an absence of large, tangled heads. The effect of three widths of spacing and three heights of wirework on the pattern of growth, yield and resin production has been studied at Wye on four varieties of hops. The effect of these treatments on pattern of growth has confirmed American experience. Over three seasons, wider planting has increased yield per plant, but this has not compensated for the reduction in plant population and yield per acre has fallen. The effect of higher wirework has been less marked but the trend has been for both yield per plant and yield per acre to rise. The influence of both height and spacing treatments on the percentage resins content of hop cones has been erratic and related to seasonal conditions. Resin yield per acre, however, is largely governed by crop yield, and has shown similar treatment responses. The conclusion reached is that growers should aim for higher wirework, rather than wider planting, in growing hops for the machine.

## Introduction

Hops were introduced into England from Flanders in the 16th century and the method of growing the plants, in which the bines were trained up tall poles, remained virtually unchanged until the third quarter of the 19th century. From about 1860 onwards, however, systems of wirework began to be introduced and are now almost universal.

Experiments designed to compare the effect of different systems of wirework on hop growth and yield were started at Wye by Hall (1903) and his colleagues, at the end of the 19th century, particular attention being paid to the effect of width of spacing. These trials were discontinued, however, when Hall left Wye in 1902 and it was not until some 30 years later that Beard (1934, 1937, 1945) recommenced work on the effect of width of spacing as part of a

programme of hop investigations initiated at East Malling Research Station. Beard showed that, under the conditions of his experiments, yield *per hill* was increased by wider spacings but yield *per acre* decreased; with the stronger growing varieties, however, this effect was much less pronounced. More recent experiments by Keller (1953) in the U.S.A. with the American Cluster variety, have lent support to Beard's findings.

All these experiments, however, were carried out at a constant height of wirework, and the effect of variation in height on hop growth has not previously been studied. Until very recent times it has been customary in England to grow hops on 12-14 ft. wirework, this height probably being governed, to some extent, by the type of spraying equipment used in the early days and by the length of suitable poles commonly available. It is well known, however, that hops can grow to considerably greater heights, and, prior to the introduction of wirework, there are records of hops growing satisfactorily on 25 ft. polework (Manwaring, 1855); furthermore, in many other European hop-growing countries, wirework 20-25 ft. high is customary at the present time and has been for many years.

In the U.S.A., mechanization of harvesting has caused hop growers to modify their cultural practices so as to produce the type of growth considered most suitable for machine picking, and there is no doubt that wide spacing and high wirework are important factors influencing such growth (see Report of the Hop Industry Productivity Team, 1951). A similar trend towards mechanization in England has prompted research into the production of hops for machine picking. With the transfer to Wye, in 1950, of part of the experimental work previously carried out at East Malling, investigations were started with this object in view and a trial was laid down in Wye Field hop garden. It had been intended to take crop records over a 5-year period before attempting to draw conclusions from the results, but owing to an outbreak of progressive *Verticillium* wilt the experiment had to be grubbed in 1955. In this article, information given in earlier progress reports (Thompson and Beard, 1954, 1955 and 1956) is summarized and discussed and tentative conclusions are drawn.

## Experimental Methods

The treatments tested comprised three heights of wirework, 13 ft., 15 ft. and 17 ft. 3 in., combined with three spacings in one direction of 6 ft., 7 ft. 6 in. and 9 ft. The cross spacing was uniform

at 6 ft. 6 in. to facilitate cross cultivation. Considered as a square plant the spacings were approximately 6 ft., 7 ft. and 7½ ft. square respectively.

The treatments were tested on the following four hop varieties, selected to give a range of growth characteristics:

Fuggle "N": A standard commercial variety of relatively weak growth; early mid-season in ripening.

John Ford: A new (Wye) variety of moderate vigour but with very short laterals; mid-season in ripening. Bred from the old English Golding hop.

Bullion: A new (Wye) variety, late mid-season and of very vigorous growth. Bred from a Canadian wild hop.

Brewer's Gold: A sister seedling of Bullion, with very similar growth characteristics but appreciably later in ripening.

All plots received standard treatment with regard to cultivations, manuring, and pest and disease control. The varieties Fuggle and John Ford were planted as layer cuttings in 1951; Bullion and Brewer's Gold were planted as rooted cuttings ("bedded sets") at the same time.

All the plants were well established by 1953 and crop records were taken in this and the succeeding two years. In 1953 only green weights were recorded, but in 1954 and 1955 samples of hop cones were taken for dry matter determinations, and for resin analysis by the method of Ford and Tait (1932). Observations on the pattern of growth were made in each growing season.

## Results

### *Pattern of growth*

In growing hops for machine picking the aim is to produce a strong bine with the fruiting laterals distributed evenly along the bine and bearing a good crop of cones. With this type of growth, bine breakage is reduced to a minimum and the picking mechanism can be adjusted to give maximum output, with an even flow of stock containing a high proportion of whole cones. Where big "heads" are produced, the matted growth tends to be broken off and this can result in either the head being discharged partly picked or the bine becoming entangled with the picking fingers and so clogging the mechanism.

In the present experiment, while it was not possible to make a detailed analysis of the growth patterns produced by the different treatments, a visual assessment of each of the plots was made

towards the end of the growing season, in August, in each of the three years 1953-55. These records show that, with the strong-growing varieties Bullion and Brewer's Gold, the widest spacing (9 × 6½ ft.) and highest wirework (17¼ ft.) produced the type of growth considered most suitable for the machine; with the weaker-growing varieties, Fuggle and John Ford, though the trend was similar it was not so pronounced and growth with the medium spacing (7½ × 6½ ft.) and medium wirework (15 ft.) could generally be regarded as satisfactory for the machine.

With the narrowest spacing and lowest wirework all varieties produced heavy "heads", and few, if any, hops on the lower laterals —the type of growth considered least suitable for machine picking. With the highest wirework, however, "heads" were absent, even at the narrowest spacing, with Fuggle and John Ford, but this did not occur with the stronger-growing Bullion and Brewer's Gold until the spacing was increased to 7½ × 6½ ft.

*Crop Yield.*

The results obtained, in terms of yield per plant and yield per acre, for the three years of the experiment, are summarized in Tables 1 and 2 respectively.

*Yield Per Plant*

The striking feature is the marked increase in yield per plant with increase in width of spacing, an effect which for the three-year

TABLE 1

EFFECT OF HEIGHT AND SPACING ON YIELD PER PLANT

(Results represent mean values for the 3 years, 1953-55, and are expressed as lb. dry hops)

| Variety | Height | | | Spacing (× 6½ ft.) | | |
|---|---|---|---|---|---|---|
| | 13 ft. | 15 ft. | 17¼ ft. | 6 ft. | 7½ ft. | 9 ft. |
| Fuggle "N" .. | 2·49 | 2·70 | 2·67 | 2·27 | 2·65 | 2·94 |
| John Ford .. | 2·95 | 3·10 | 3·15 | 2·72 | 3·13 | 3·37 |
| Bullion .. .. | 3·59 | 3·69 | 3·92 | 3·16 | 3·69 | 4·34 |
| Brewer's Gold .. | 3·36 | 3·33 | 3·45 | 2·82 | 3·45 | 3·87 |

Standard errors:

| | *Height* | *Spacing* |
|---|---|---|
| Fuggle .. .. .. .. | ± 0·071 | ± 0·073 |
| John Ford .. .. .. .. | ± 0·169 | ± 0·109 |
| Bullion .. .. .. .. | ± 0·171 | ± 0·129 |
| Brewer's Gold .. .. .. | ± 0·118 | ± 0·085 |

TABLE 2

EFFECT OF HEIGHT AND SPACING ON YIELD PER ACRE

(Results represent mean values for the 3 years, 1953-55, and are expressed as cwt. dry hops)

| Variety | Height | | | Spacing (× 6½ ft.) | | |
|---|---|---|---|---|---|---|
| | 13 ft. | 15 ft. | 17¼ ft. | 6 ft. | 7½ ft. | 9 ft. |
| Fuggle "N" .. | 20·09 | 21·75 | 21·52 | 22·62 | 21·18 | 19·56 |
| John Ford .. | 23·95 | 25·09 | 25·45 | 27·19 | 24·91 | 22·40 |
| Bullion .. .. | 28·80 | 29·52 | 31·69 | 31·66 | 29·53 | 28·85 |
| Brewer's Gold .. | 26·94 | 26·66 | 27·85 | 28·05 | 27·61 | 25·79 |

Standard errors:

| | *Height* | *Spacing* |
|---|---|---|
| Fuggle .. .. .. .. | ± 0·601 | ± 1·006 |
| John Ford .. .. .. .. | ± 1·509 | ± 0·983 |
| Bullion .. .. .. .. | ± 1·369 | ± 1·103 |
| Brewers' Gold .. .. .. | ± 1·013 | ± 0·749 |

means (Table 1) is significant at each increase in spacing for all varieties with the exception of John Ford, where the yield difference between the 7½ ft. and 9 ft. spacings just fails to reach significance.

The influence of height of wirework on yield per plant is not so clear cut and is more subject to seasonal variations. Nevertheless, as can be seen from Table 1, over the three-year period of the experiment the general trend is for yield to rise as the height is increased, although the only significant difference is that between the 13 ft. and 15 ft. heights with the Fuggle variety.

*Yield Per Acre*

As with yield per plant, the influence of spacing is the dominant effect, and with the weaker-growing varieties the decrease in yield per acre with increase in width of plant is virtually linear. With the stronger-growing varieties Bullion and Brewer's Gold, however, the spacing effect is less pronounced and consistent. As the influence of height of wirework on yield per acre directly reflects the effect of this treatment on yield per plant, comparable results are found.

*Resins Content*

The results obtained from the analysis of samples of cones taken from the different treatments in 1954 and 1955, are given in Table III.

Discussion

It will be seen from the data given above that, though increase in width of spacing causes a rise in yield per hill, this does not compensate for the reduction in plant population, and yield per acre falls. Thus, in the present experiment, increasing spacing from 6 ft. × 6½ ft. to 9 ft. × 6½ ft. is equivalent to the loss of one-third of the land under hops and to make good this loss requires a 50 per cent. increase in yield per hill; in fact, the increases found over the three-year period of the experiment have been 37 per cent. with Bullion and Brewer's Gold, 30 per cent. with Fuggle and 24 per cent. with John Ford.

The response to wider spacing is clearly varietal and, as might be expected, Bullion and Brewer's Gold are strong-growing hops producing very long laterals and so likely to benefit from more space. In contrast, Fuggle is a variety of medium strength and John Ford is a relatively weak variety, with characteristically short laterals. Beard recorded similar differences in response to wider spacings between the relatively weak-growing Wye seedling L21, and the stronger-growing OP21 (Brewer's Favourite) and suggested that with increasing vigour of a variety the yield per hill might approach the point where it compensated for the fewer hills per acre. In practice this seems unlikely, and it is noteworthy that Keller (1953) in the U.S.A. found that with the strong-growing and long-lateral producing Oregon Cluster variety, the rate of increase of yield per plant dropped appreciably as the planting distance was extended in 2 ft. intervals from 8 ft. × 2 ft. to 8 ft. × 8 ft. It is also of interest that Keller found that with a reduction in plant population of one-third, the increase in yield per hill was 37 per cent. with the Oregon Cluster variety—the same figure as found at Wye with Bullion and Brewer's Gold, varieties having growth characteristics similar to those of Oregon Cluster.

It should perhaps be pointed out that both Bullion and Brewer's Gold were grown with only one bine per string (i.e. four bines per hill) in contrast to the more usual two bines per string trained with the weaker growing varieties such as Fuggle. Training two bines per string with Bullion and Brewer's Gold might have increased the yield per hill at the wider spacings but this seems unlikely in view of earlier work by Beard (1937) and Keller (1953), in which it was found that number of bines per string was not a major factor influencing yield.

During the period of the experiment at Wye, it was not possible to make detailed measurements of the pattern of growth and cone production with the different treatments but in the 1955 harvest

## Table 3

### Effect of Height and Spacing on Resins Content of Hops

Results for total soft resin (T.S.R.), α resin and β resin expressed as % dry hops

| Variety | Year | Height | | | | | | | | | Spacing | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 13 ft. | | | 15 ft. | | | 17½ ft. | | | 6 × 6½ ft. | | | 7½ × 6½ ft. | | | 9 × 6½ ft. | | |
| | | T.S.R. | α resin | β resin | T.S.R. | α resin | β resin | T.S.R. | α resin | β resin | T.S.R. | α resin | β resin | T.S.R. | α resin | β resin | T.S.R. | α resin | β resin |
| Fuggle "N" .. | 1954 | 10·43 | 3·79 | 6·64 | 10·51 | 3·79 | 6·72 | 10·98 | 3·85 | 7·13 | 10·56 | 3·89 | 6·67 | 10·51 | 3·76 | 6·75 | 10·85 | 3·78 | 7·07 |
| | 1955 | 12·27 | 4·82 | 7·45 | 11·70 | 4·55 | 7·15 | 12·14 | 4·96 | 7·18 | 12·34 | 4·82 | 7·52 | 12·06 | 4·72 | 7·34 | 11·70 | 4·78 | 6·92 |
| | Mean | 11·35 | 4·31 | 7·05 | 11·11 | 4·17 | 6·94 | 11·56 | 4·41 | 7·16 | 11·45 | 4·36 | 7·20 | 11·29 | 4·24 | 7·05 | 11·28 | 4·28 | 7·00 |
| John Ford .. | 1954 | 15·87 | 7·14 | 8·73 | 16·19 | 7·32 | 8·87 | 16·87 | 7·80 | 9·07 | 15·68 | 7·26 | 8·42 | 16·29 | 7·40 | 8·89 | 16·96 | 7·61 | 9·35 |
| | 1955 | 18·25 | 8·93 | 9·32 | 18·58 | 9·40 | 9·18 | 19·38 | 9·59 | 9·79 | 19·03 | 9·56 | 9·47 | 19·21 | 9·54 | 9·67 | 17·97 | 8·82 | 9·15 |
| | Mean | 17·06 | 8·04 | 9·03 | 17·39 | 8·36 | 9·03 | 18·13 | 8·70 | 9·43 | 17·36 | 8·41 | 8·95 | 17·75 | 8·47 | 9·28 | 17·47 | 8·22 | 9·25 |
| Bullion .. .. | 1954 | 16·11 | 6·30 | 9·81 | 16·44 | 6·71 | 9·73 | 17·57 | 6·49 | 11·08 | 16·60 | 6·52 | 10·08 | 16·76 | 6·47 | 10·29 | 16·76 | 6·50 | 10·26 |
| | 1955 | 17·89 | 7·60 | 10·29 | 17·92 | 7·37 | 10·55 | 18·04 | 7·60 | 10·44 | 18·13 | 7·63 | 10·50 | 18·10 | 7·72 | 10·38 | 17·62 | 7·23 | 10·39 |
| | Mean | 17·00 | 6·95 | 10·05 | 17·18 | 7·04 | 10·14 | 17·81 | 7·05 | 10·76 | 17·37 | 7·08 | 10·29 | 17·43 | 7·10 | 10·34 | 17·19 | 6·87 | 10·33 |
| Brewer's Gold .. | 1954 | 16·65 | 6·99 | 9·66 | 16·65 | 7·77 | 9·88 | 16·62 | 6·81 | 9·81 | 16·75 | 7·00 | 9·75 | 16·38 | 6·68 | 9·70 | 16·79 | 6·89 | 9·90 |
| | 1955 | 17·02 | 7·63 | 9·39 | 17·83 | 7·67 | 10·16 | 17·57 | 7·68 | 9·89 | 18·35 | 7·86 | 10·49 | 16·91 | 7·45 | 9·46 | 17·16 | 7·67 | 9·49 |
| | Mean | 16·84 | 7·31 | 9·53 | 17·24 | 7·22 | 10·02 | 17·20 | 7·25 | 9·85 | 17·55 | 7·43 | 10·12 | 16·65 | 7·07 | 9·58 | 16·98 | 7·28 | 9·70 |

records of the distribution of hop cones along the bine in the variety Brewer's Gold were taken from four hills, one in each of the contrasting height and spacing treatments. It was observed that the length of bine produced remained consistently at some 20-21 ft. whether the hops were grown on 13 ft. or 17¼ ft. wirework or at 6 ft. or 9 ft. spacing. Further, while it was clear that a greater percentage of the crop was produced in the first 4 ft. of bine above the tie-in string (i.e., above 4 ft. 6 in.) with the wider spacings and higher wirework, the main bulk of the crop was located in the top 12 ft. of bine irrespective of the treatment. Further research is needed to find out if the heavier yields produced, particularly at the wider spacings, are due to a greater number of cones or to individual cones growing out more and so increasing in weight; the effect is probably due to a combination of factors.

In the present experiment the effect of the different height and spacing treatments on the resins content of the cones was found to be influenced by weather conditions. Thus in 1954, a year when summer temperatures were exceptionally low and hours of sunshine well below average, the trend with all four varieties was for resins to rise with increase in height; the spacing effect was not so clear cut, but here also the tendency was for resins to rise with the wider spacings. In 1955, weather conditions with regard to summer temperatures and sunshine, though only average, were appreciably better than in 1954 and were reflected in a general increase in alpha resin and in total soft resins with all varieties. This rise in resins associated with improved weather conditions appears to have offset the beneficial effect of higher wirework and wider spacing recorded in 1954, and in 1955 resins content decreased at the wider plantings and showed erratic effects with the higher wirework though the general trend in the latter case was for resins to rise slightly.

When resin production is considered in terms of yield per acre, however, it would appear that crop yield is the dominant factor and over-rides variations in percentage resin content of the cones. Thus, resin yield has been found to rise consistently with higher wirework and to show a marked falling off with increase in width of planting, with all varieties, in both seasons.

## Conclusions

The object of the present experiment was to ascertain the combination of height and spacing which would produce the type of growth considered to be most suitable for machine picking, while at the same time giving satisfactory crop yield and resin

production. It has been shown that close planting results in a pattern of growth unfavourable for machine picking and, in addition, while close spacing results in increased yield per acre, a number of factors other than yield influence the planting distance likely to be adopted in practice. Thus the size of implements (e.g. tractors and sprayers) which can be used most economically governs row widths and increase in plant population results in a greater outlay per acre on materials such as string and in higher costs for hand labour for dressing, stringing and training the hills. Further, the dense, housed-in growth which tends to be produced with close planting renders the crop more liable to attack by fungus diseases such as Downy Mildew and Mould, with consequent increased costs for disease control plus the risk of lower valuations for damaged cones.

Increasing the height of wirework encourages an even distribution of the cones along the bine with an absence of large, tangled heads of hops, which makes for easier picking on the machine. Since, over the three-year period of this experiment, this result has been achieved without having the unfavourable effect on crop and resin yield shown by increasing the width of spacing, it has been recommended that growers should take account of these findings when erecting new wirework.

From present knowledge, on a deep brick-earth type of soil the most satisfactory combination of height and spacing for strong-growing varieties such as Bullion would appear to be 17 ft. wirework and 7 ft. $\times$ 7 ft. plant, and for the weaker growing varieties such as Fuggle, 15 ft. wirework and $6\frac{1}{2}$ ft. $\times$ $6\frac{1}{2}$ ft. plant.

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# A NOTE ON THE DETERMINATION OF THE PEROXIDASE CONTENT OF HOP PLANTS

E. W. Weston

## Summary

An account is given of an improved method of determining the peroxidase contents of hop cones and leaves, in which a single colorimetric measurement only is required for each determination.

Using this method a correlation was sought between the peroxidase contents and the ratio $\frac{\text{per cent. } \alpha\text{-resin}}{\text{per cent. } \beta\text{-resin}}$ in the cones of 54 seedling varieties taken at random. A non-significant negative correlation was obtained.

## Introduction

The formation of humulone from lupulone by oxidation has been shown by Schild and Raum (1956) to occur *in vitro* under the influence of light. A similar reaction may take place in the hop cone during growth, and this supposition is in agreement with the noticeable increase of the α-resin fraction in those seasons with more than average sunshine. If this view of the synthesis of hop resins is correct it is possible that the oxidation involved may also be promoted by an enzyme such as peroxidase, which has already been shown to occur in hops.

## Analytical and Sampling Techniques with Leaves

A method of analysis for peroxidase was developed by Tatchell (1953) as a modification of a previous method (Wallerstein *et al.*, 1948). The method uses o-phenylene diamine as acceptor, which, in the presence of peroxidase and hydrogen peroxide is converted into the highly coloured 2:3 diamino phenazine and this latter is determined colorimetrically in the Spekker photoelectric absorptiometer.

The colour density increases with time after mixing until a steady maximum is reached after about 90 minutes and it is this reading which is normally taken. Variation in the concentration of hydrogen peroxide also causes a variation in the density of colour and a maximum is reached for a given concentration, the colour being less for higher or lower concentrations. The height of

the peak gives a measure of the enzyme. The position of this peak is also dependent upon the enzyme concentration so that it is not possible to select a standard hydrogen peroxide concentration for all measurements.

Tatchell avoided this difficulty by taking four measurements using different quantities of hydrogen peroxide and estimating the peak measurement by interpolation. In the present work the method which Tatchell used was modified slightly so that more convenient volumes of solutions were employed and was used to measure the peroxidase contents of hop leaves.

Initially 5 gm. of fresh Fuggle N leaf were ground in a mortar with a little sand and the macerate, together with 10 ml. sodium acetate buffer solution (sodium acetate 2M+glacial acetic acid to give a pH 4·3) made up to 500 ml. in a volumetric flask. After shaking for 15 minutes and filtering, aliquots of the enzyme extract were taken for analysis. At first the aliquots were too great to give a peak within the range of hydrogen peroxide concentration used, so a standard aliquot of 5 ml. of enzyme extract was diluted to 100 ml. and the reaction carried out with 50 ml. of the diluted extract. Within the range 1 ml.-4 ml. of 0·5 per cent. hydrogen peroxide maximum colour density readings were obtained for most of the leaf samples studied.

Using a standard 5 ml. of enzyme extract the peroxidase contents of a series of leaves, taken from various positions on one bine of a Fuggle N plant, were measured. The curves obtained showed that peroxidase contents were low in young tissue until the first fully expanded leaf. The content was found to increase rapidly with age of tissue to a certain point after which it remained relatively constant; the leaf on the 8th node from the growing point had nearly the same peroxidase content as one taken from the 14th node (12 in. from ground level).

It appeared from this experiment that when comparing one plant with another a well developed leaf, low on the bine, should be used.

The determination of peroxidase in two plants of different variety showed that there was considerably more peroxidase in both young and old leaves of Fuggle than in corresponding leaves of Northern Brewer and also showed that the method was of sufficient accuracy to distinguish normal variations of peroxidase between one plant and another.

A series of peroxidase measurements were made on leaves taken from plants of different variety whose resin characters had

been determined during the previous year. When curves were plotted it was apparent that when the peak was a high one there was considerable difficulty in interpolating and in some cases it was not clear whether the curve was ascending or descending at a measured point. None of a number of algebraic formulae which were postulated gave curves which agreed with those obtained practically so that the position of a peak could not be obtained by calculation. To see more clearly how curves for different concentrations of enzymes were related, measurements were made with

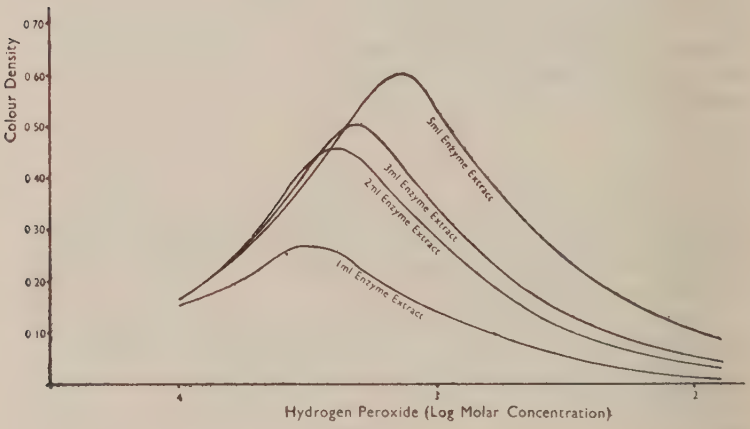


FIG. 1.

20 different concentrations of hydrogen peroxide for each of a number of dilutions of the same enzyme extract.

From Fig. 1 it can be clearly seen that at low concentrations of hydrogen peroxide all curves tend towards each other and this explains the difficulty in interpolation when three of the four points measured in the previous experiment lay on this side of the peak. The peaks were much narrower than had been expected again explaining previous difficulties. All measurements for each enzyme dilution were made on the same day but each dilution from the original extract, which was stored at a low temperature, was made on a different day. As a result of the slight increase of activity which occurs during storage the peaks do not show the expected relationships with one another. On the side of the peaks corresponding to

high peroxide concentrations the curves maintain the same positions relative to one another as do the peaks themselves. Thus by selecting a concentration of hydrogen peroxide to give a reading on this side of the peak a measurement of enzyme concentration should be possible.

This possibility was tested using six standard dilutions of a given extract for each of three peroxide concentrations in this

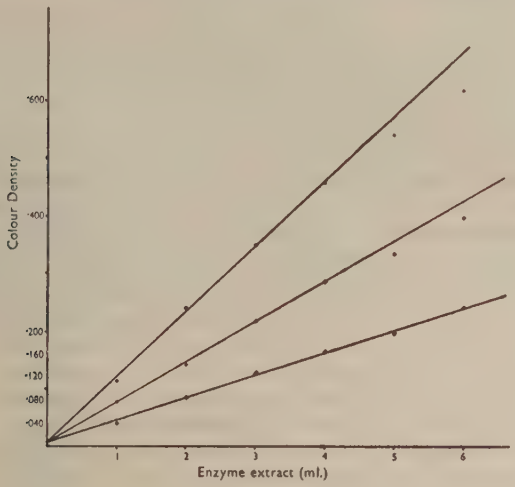


FIG. 2.

region. The results indicate that providing the points obtained are far enough from the peaks the colour densities are proportional to enzyme concentration (Fig. 2). Unfortunately the greater the linearity the smaller the colour range; this range may, however, be increased by using longer optical cells and if necessary increasing the aliquots taken after colour development while maintaining the same degree of dilution with acetone.

From the figures obtained here it may be seen that using 4 ml. of 2 per cent. hydrogen peroxide adequate linearity is obtained up to a colour density reading of at least 240. A standard method was therefore adopted using 5 ml. of 2 per cent. hydrogen peroxide and suitable aliquots of enzyme extract to avoid exceeding the linearity of the curve.

### Peroxidase Analysis of Hop Cones

This revised method was applied to the analysis of hop cones as follows. A sample of hop cones was dried in a vacuum desiccator for 48 hours and a 1 gm. sample of the dried cones rapidly weighed out and ground finely with a pestle and mortar. Resin was removed by washing the ground material with ethyl ether and filtering through Whatman No. 4 paper. This resin extract was later used for the determination of alpha and total soft resins.

When the resin had been removed the ether was allowed to evaporate from the ground material which was then washed with the diluted buffer solution, previously described, into a 100 ml. measuring flask and made to the mark. This was shaken for 15 minutes and then filtered through Whatman No. 1 paper; 50 ml. of this extract were taken for analysis, 5 ml. of 1 per cent. o-phenylene diamine solution and 5 ml. of 2 per cent. hydrogen peroxide solution then added and after mixing allowed to stand at room temperature for 90 minutes. The hydrogen peroxide solution was prepared and standardized against a solution of sodium thiosulphate each day shortly before use since it is unstable. A 5 ml. aliquot of the reaction solution was pipetted after 90 minutes, when it had reached a constant colour density, into a 50 ml. volumetric flask and made to the mark with acetone. The optical density of this solution was then measured in the Spekker absorptiometer using the Ilford spectrum blue 602 filter.

The acetone was originally added to stop the reaction but since sampling was only carried out when a steady state was reached, its use might appear to have been unnecessary. This possibility was tested and the reaction solution itself was taken for colour measurement. The curve obtained using known dilutions of the same enzyme extract was far from linear, however, and dilution with acetone was retained.

### Relationship between Peroxidase and Resin Contents of Hop Cones

Enzyme contents of a series of kiln dried hop cone samples were determined, together with their alpha and total soft resin contents. The results obtained using 54 hop samples from a random collection of seedling varieties show that the ratio $\frac{\text{per cent. } \alpha\text{-resin}}{\text{per cent. } \beta\text{-resin}}$ is negatively correlated with peroxidase content but not significantly so ($r = -0{\cdot}213$).

Since the samples had been stored for about 6 months before analysis the negative correlation could be explained by assuming that hop alpha resin is affected during storage by peroxidase. Tatchell (1954), however, concluded from his experiments involving measurements of resin deterioration under various storage conditions "that the deterioration of hop resins, particularly the varietal characteristic of this phenomenon, is unaffected by hop peroxidase".

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# THE USE OF SYSTEMIC ORGANO-PHOSPHORUS INSECTICIDES IN HOPS WITH REFERENCE TO THE RATIO OF FRESH TO DRIED CONES IN THE RESULTING CROP

H. S. Darling

## Summary

In England the use of systemic organo-phosphorus insecticides for the control of the Hop Aphis (*Phorodon humuli*) and the Hop Red Spider Mite (*Tetranychus urticae*) has become general since 1949. The compound most widely used at first was schradan but at present schradan, dimefox and demeton methyl are all in common use.

Data obtained from five farms suggest that the use of these compounds has been associated with an increase in the volume of fresh hops required to give a hundredweight of dried and pressed hops which have been cured to commercial standards of about 9 per cent. water content.

This increase in the ratio of fresh to dried hops has resulted in increased costs of picking and drying the crop. This cost increase, however, has been more than paid for by the improvement in yield and quality obtained through the use of these insecticides.

## Introduction

The main pest control problems of the English hop grower are concerned with the Hop Aphis (*Phorodon humuli* Schr.) and the Hop Red Spider Mite (*Tetranychus urticae* Koch), both of which attack the foliage and the cones during the summer months. The Hop Aphis by means of its long and slender stylets sucks the fluid contents of the phloem strands in the vascular bundles; the Hop Red Spider, with its small and short mouth-parts, sucks the sap from individual cells of the epidermis and the immediately underlying cell layers.

Of these two pests, the Hop Aphis is the more serious under English conditions. Both pests are at present controlled by systemic organo-phosphorus insecticides applied during May, June and July.

## The Hop Aphis

This pest spends the winter in the egg stage on alternate host plants of the genus *Prunus*, of which hosts the most important under English conditions are the sloe and the damson. The winter

eggs hatch in the spring and the resulting aphids multiply on the young foliage of the *Prunus* without causing obvious damage. In mid-May winged females are produced which migrate to hop plants; this migration may continue until late July or early August.

The winged migrants infest the young leaves of hops and there reproduce asexually to give wingless females. These reproduce very rapidly and asexually on the lower surfaces of the leaves through a number of wingless generations to give large populations which, if no control measures are taken, can greatly weaken the plants. In severe attacks little or no crop is formed and plants may be killed outright.

Winged adults appear on the hop plants in early autumn and a return migration to the winter host then takes place. On *Prunus*, sexual reproduction occurs giving rise to the egg stage in which the species passes the winter.

Damage caused during the summer is obviously of great importance. Of hardly less importance is the late attack which may develop during September in the cones. Such attack usually results from populations surviving from insecticidal treatments which were applied in the summer and which gave sufficient control to permit of normal plant growth and development. Aphids occurring between the bracts and bracteoles of the hop cones are protected from applications of contact insecticides and can increase to an extent sufficient to reduce the quality of the ripening crop, and in severe attacks, to destroy it completely.

### The Hop Red Spider Mite

This pest over-winters as adults which hibernate in soil and rubbish, in cracks in hop poles and even inside the strands of hop wirework. These adults, which are typically red in colour, leave their hiding places in the spring and climb on to the young bines. There they feed on the lower surfaces of the leaves, being protected to a greater or lesser extent by fine silk webbing which they spin. As the bines grow, the mites migrate towards the growing points so that the young leaves are infested as they develop.

Reproduction can be very rapid, the adults produced in the summer being greenish-yellow in colour instead of red as in the winter adults. In the absence of control measures, very large populations may develop with consequent heavy damage to leaves and cones. Affected tissues turn brown and often die; the health and vigour of the plants may be greatly reduced, and in bad years the crop may be destroyed.

CONTROL

Both pests have a high reproductive rate and both feed mainly on young and rapidly growing tissue. Treatments with contact insecticides have to be repeated at very frequent intervals if populations are to be adequately controlled and new young growth protected. This is especially the case with the Hop Aphis during June and July when the rapid elongation of the bines means that new leaves are continually being exposed to attack, and when fresh migrants are continually arriving to recolonize treated plants.

Before World War II the only suitable contact insecticides available to the English grower were nicotine and derris. During the war DDT and BHC were developed only to be superseded in the post-war years by the organo-phosphorus compounds TEPP and parathion. The last two had the advantage of being equally effective against aphids and red spider. Earlier insecticides were relatively ineffective against red spider. Even with TEPP and parathion however, good control of these pests was not easily achieved and losses through their attack were common.

In 1949 a great advance took place for English growers with the appearance of the systemic insecticide, schradan, (*bis* dimethylaminophosphonous anhydride), on a commercial scale. Field trials showed that this organo-phosphorus chemical, when applied as a spray at the rate of from 0·5 to 1·0 lb. (230-460 gm.) of active ingredient per acre, was absorbed and translocated systemically in the sap to all parts of the plant in sufficient quantity to give virtually complete control of aphids and red spider for three or four weeks. It was found that two, or at the most three, suitably timed sprayings during the summer not only eliminated the Hop Red Spider for the season, but also gave such complete control of the Hop Aphis during the invasion period that few if any aphids survived to infest the developing cones in August. By comparison with then existing insecticides its use increased yields by 10 per cent.-20 per cent. by weight of dried hops (Ripper, Greenslade and Hartley, 1950) and gave improved quality.

This new insecticide became very popular and by 1954 the majority of English hop growers were using schradan. By contrast the systemic compound demeton (diethyl ethylmercaptoethylthionphosphate), which was developed at the same time and is now widely used outside England, has never become popular. This unpopularity is due partly to the fact that demeton while very potent against red spider does not always give consistent results against aphids under English conditions, and partly to the regulations made by

the English Ministry of Health concerning its application, which are so strict as to interfere with its use in hops.

The only serious drawback to schradan under English conditions is the need for 24 hours dry weather after spraying to allow it to be absorbed by the plants. Should rain fall during this period part of the insecticide may be washed off the leaves and the efficacy of the spray be correspondingly reduced. Another feature of schradan is that while strongly systemic in action it is only a weak contact insecticide. This is claimed as an advantage by those entomologists who prize the biological control value of predacious and parasitic insects, but is regarded as a disadvantage by those growers who desire a "knock-down" as well as a systemic effect.

Two other new organo-phosphorus insecticides have become commercially available to English hop growers during the past three years. These are dimefox (bis dimethylaminofluorophosphine oxide) and demeton methyl (a homologue of lower mammalian toxicity than demeton).

Dimefox is extremely toxic to man and farm animals and may not be used in England as a spray because of the hazards involved. It is therefore applied via the soil to the crown of the hill at the base of the bines. The normal recommended dose of 0·5 gm. active ingredient in 125 ml. water per plant, or about 1 lb. per acre, gives up to two months protection against aphids and red spider and the control obtained may under certain conditions surpass that given by schradan (Emery, 1954: Darling and Derbyshire, 1956, 1957). The application of dimefox is unaffected by rain or wind and is thus largely independent of the weather, a great advantage under English conditions. This insecticide has become popular with many growers and perhaps a third of the English hop crop is at present being treated with it. Its main disadvantages are, first, if the weather is cold, translocation of the insecticide is delayed and control may be poor for part of the season; second, if the crown of the hill is diffuse and the bines arise from a wide area, some of the bines may escape treatment.

Demeton methyl is less toxic to man and farm animals than either dimefox or schradan, and in addition to being strongly systemic in its action is also a powerful contact insecticide. It has rapidly become very popular with English growers and appears to be replacing schradan as a standard spray for aphid and red spider control. Field observations suggest that it is more quickly absorbed by the plant than schradan and is therefore less affected by rain falling shortly after application. It is normally applied as a spray

two or three times during the season at dosages very similar to those used for schradan. Its main disadvantage is a strong and unpleasant smell.

The advent of these systemic compounds has brought about a revolution in pest control in English hop gardens and is perhaps the biggest single technical improvement that has taken place in the industry in the past thirty years.

An important factor in the success of systemic insecticides in hop production is the time relative to the growth of the crop when they are used. The Hop Aphis and the Hop Red Spider are both controlled by applications made mainly during June and July. This means that these highly poisonous chemicals are present in the plants in appreciable concentrations before the production of the hop cones. During August when the cones are developing the concentration of insecticide in the sap is allowed to fall rapidly so that only safe levels of toxic residues occur in the ripe cones. (Laws and Darling, 1958).

### Ratio of Green to Dried Hops

When hops are picked by hand the farmer pays for the work in terms of the number of bushels of green hops harvested. The bushel is a measure of volume, nominally 8 gallons or 36 litres, which in hop picking is estimated by means of special baskets. The bushel as measured varies from place to place, but estimates on the same farm under the same system of management usually remain reasonably constant from year to year. At the end of each harvest the farmer's accounts give him an accurate total of the number of bushels of green hops or "green bushels" picked that season.

In England the green hops are kiln dried by the farmer to a water content of about 9 per cent. and the dried hops thus cured are then pressed into bales or pockets each comprising about 75 kgm. or one and a half hundredweights. These dried hops are sold by weight and from his accounts the farmer has an accurate record of the total number of hundredweights produced each season.

Some growers keep a year to year record of the average ratio of green bushels per cwt. of dried hops; this figure is obtained by dividing the total number of bushels by the total number of cwt. for each season. This is known as the bushel/cwt. ratio. This ratio varies considerably from year to year on the same farm, and from farm to farm in the same year as is shown by Table 1. This variation has been discussed by Glasscock (1939) who suggested that the main

TABLE 1

VALUES FOR THE RATIO OF BUSHELS OF GREEN HOPS HARVESTED TO CWT. OF DRIED HOPS MARKETED FOR FIVE HOP FARMS IN EAST KENT DURING THE YEARS 1942-57 INCLUSIVE

| Year | Bushel/cwt. ration values for five farms in East Kent | | | | | Average ratio for all farms |
|---|---|---|---|---|---|---|
| | Wye College | Farm "E" | Farm "H" | Farm "M" | Farm "W" | |
| 1942 | — | 109 | 77 | 92 | — | 93 |
| 1943 | — | 103 | 88 | 94 | — | 95 |
| 1944 | — | 96 | 88 | 86 | 91 | 90 |
| 1945 | — | 98 | 88 | 93 | 100 | 95 |
| 1946 | — | 89 | 87 | 90 | 85 | 88 |
| 1947 | — | 89 | 89 | 91 | 88 | 89 |
| 1948 | — | 99 | 83 | 88 | 85 | 89 |
| 1949 | 100 | 99 | 86 | 84 | 89 | 92 |
| 1950 | 100 | 110 | 89 | 93 | 94 | 97 |
| 1951 | 114 | 112 | 96 | 97 | 99 | 104 |
| 1952 | 103 | 115 | 97 | 97 | 99 | 102 |
| 1953 | 120 | 115 | 92 | 95 | 93 | 103 |
| 1954 | 127 | 111 | 87 | 96 | 93 | 103 |
| 1955 | 115 | 110 | 98 | 100 | 107 | 106 |
| 1956 | 127 | 120 | 88 | 97 | 108 | 108 |
| 1957 | 125 | 125 | 87 | 105 | 107 | 110 |

factors concerned are the proportion of large to small cones, the seed status of the cones, and climatic moisture conditions at picking time.

During recent years it has been reported that the bushel/cwt. ratio was increasing beyond the limits of normal variability (Darling and Derbyshire, 1956). Data were therefore examined from Wye College farm and from four other East Kent farms designated "E", "H", "M" and "W" respectively. The findings are summarized in Table 1.

In Farm "E" data are available for the 16 year period 1942 to 1957. For the first eight years 1942-49 the ratio averaged 98; for the second eight years 1950-57 the average was 115. The difference is highly significant statistically ($P=0\cdot001$).

In Farm "H", data are also available for 1942-57. Here for the first eight years 1942-49 the average value for the ratio was 86; for the second eight years 1950-57 the average value was 92. The difference is statistically significant ($P=0\cdot02$).

The data from Farm "M" also cover the sixteen years 1942-1957. For the eight years 1942-49 the ratio averaged 91. During 1950-57 the average increased to 98. Once again the difference between the two eight year periods is highly significant ($P=0\cdot001$).

In Farm "W" data are available for the fourteen years 1944 to 1957 inclusive. For the first seven years 1944-1950 the ratio averaged 90; for the second seven years 1951-57 the average was 102. Here also the difference is statistically significant ($P=0\cdot01$).

Finally, in the case of Wye College the data cover the nine years 1949 to 1957 inclusive. During the first four years, 1949-1952 the ratio averaged 104; for the next five years 1953-57 it averaged 123. The difference is statistically significant ($P=0\cdot01$).

The yearly average ratio values for the sixteen years 1942 to 1957 inclusive, obtained by combining the data for all farms, are set out in the right-hand column of Table 1. For the period 1942-49 the eight year mean of the combined values was 91; for 1950-57 the eight year mean was 104. The difference between these two periods as shown by these combined average values is highly significant statistically ($P = 0\cdot001$), and represents an increase of about 14 per cent. in the amount of green hops required to give a standard weight of dried hops.

It is clear that a considerable increase in the bushel/cwt. ratio has taken place since 1950. Of the possible factors suggested by Glasscock (1937), no information is available on cone size or seed status of hop cones for the 16 years under review. Rainfall figures are available for Wye College representing East Kent, and yearly totals and totals for August and September (the months when the cones form and ripen) have been examined. Data in terms of inches of rain for each of the 16 years 1942-57 inclusive are set out in Table 2.

Table 2

Rainfall Data (Expressed in Inches of Rain) for Wye College, Kent, for 1942-57 Inclusive

| Year | Total rainfall (inches) | August-September rainfall (inches) | Year | Total rainfall (inches) | August-September rainfall (inches) |
|---|---|---|---|---|---|
| 1942 | 26·29 | 4·53 | 1950 | 29·96 | 4·59 |
| 1943 | 22·74 | 2·67 | 1951 | 38·59 | 8·93 |
| 1944 | 25·29 | 4·48 | 1952 | 30·38 | 8·17 |
| 1945 | 20·73 | 2·83 | 1953 | 23·83 | 6·33 |
| 1946 | 35·80 | 7·01 | 1954 | 31·84 | 5·83 |
| 1947 | 24·07 | 0·90 | 1955 | 29·98 | 4·71 |
| 1948 | 22·99 | 4·47 | 1956 | 25·98 | 5·95 |
| 1949 | 25·56 | 4·08 | 1957 | 30·09 | 7·68 |

These data show that the average annual rainfall for the eight years 1942-49 was 25·43 inches. For 1950-57 the average was 30·08 inches. The difference of 4·65 inches approaches statistical significance at $P = 0{\cdot}05$.

The totals for August and September show that for 1942-49 the average precipitation for these two months was 3·87 inches. For 1950-57 this average rose to 6·52 inches, an increase of 68 per cent. The difference of 2·65 inches is statistically significant ($P = 0{\cdot}01$).

These results establish that the eight years 1950-57 were appreciably wetter than the preceding eight years, mainly because of significantly greater rainfall during the months of August and September when the hop cones develop. The possibility at once suggests itself that this increase in rainfall may have been responsible for the observed increase in the bushel/cwt. ratio.

Critical examination, however, does not fully confirm this hypothesis. In the dry eight year period of 1942-49 the 1946 season was exceptionally wet; in this year the ratio remained low on all farms. In the wet eight year period 1950-57 the 1955 summer was relatively dry; in this year the ratio remained high on all five farms. Statistical examination of the data fails to reveal any correlation between rainfall and the bushel/cwt. ratio within either of the eight year periods.

As stated above the use of systemic insecticides on hops on a commercial scale began in England in 1949 with the introduction of schradan. In the five farms under discussion the years when schradan was introduced are given below:

Farm "E": 1950
Farm "H": 1950
Farm "W": 1950
Farm "M": 1951
Wye College: 1953.

Data in Table 1 show that in each farm in the year in which schradan was introduced, the ratio rose at once to a level above the average of the previous period for which data exist. In three out of the five farms it rose to levels greater than any previously recorded. It is of great significance to note that in the case of Wye College the ratio remained low during the very wet years of 1951 and 1952; but when schradan was introduced at Wye in 1953 the ratio immediately rose to the high levels at which it has remained ever since.

It appears probable that the introduction of schradan has

played a major part in increasing the bushel/cwt. ratio. The systemic compounds dimefox and demeton methyl have since replaced schradan to a greater or lesser extent on some of the farms under discussion without any reduction in the ratio; it may be presumed that their effect in this connection is similar to that of schradan.

These findings at first sight suggest that the use of these new insecticides may have merely raised the cost of producing hops by raising the picking and drying costs by about one-seventh. It must be emphasized, however, that in addition to increasing the bushel/cwt. ratio, their use has resulted in an increase in dry weight yield per acre of the same order, i.e. 10 per cent to 20 per cent. This rise in the yield of dried hops per acre has much more than paid for the accompanying rise in picking and drying costs consequent upon the increase in the bushel/cwt. ratio. It should be noted that systemic insecticides not only increase yields but also by the high degree of pest control achieved can improve quality. Any premium paid in respect of this higher quality may further offset the increase in picking and drying costs.

The causes of this observed increase in the bushel/cwt. ratio have not been investigated. A possible explanation is that the superior control of aphids and red spider given by schradan and other systemic insecticides not only results in overall increases in the yields of dried hops, but also results in the crop being picked in a greener and more succulent condition. It is also possible, however, that the introduction of these systemic compounds into the sap may have had side effects on the physiology of the hop plant which have resulted in this increase in the ratio of fresh to dried hops.

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# HOP PROPAGATION

## I. THE GERMINATION OF HOP SEEDS

I. H. Williams and E. W. Weston

Summary

Previous research on methods of germinating hop seeds is reviewed. Recent investigations at Wye, the results of which confirm and amplify earlier findings, are described.

Low temperature treatment of presoaked seed at 4·4° C. for five to six weeks, has given consistently high levels of germination and is suggested as the most suitable method where large numbers of seeds are involved. For more rapid results, the chipping of individual seeds, or scarification in batches can be effective; the former method may be inconvenient when many seeds have to be treated.

Chemical treatments had little effect. Of the ten substances tested, only concentrated sulphuric acid had any appreciable success. Here the effect was probably due to physical action on the seed coat.

### Introduction

A technique for obtaining consistent germination of seeds is an important factor in hop research. Hop seeds do not germinate readily when sown under apparently good conditions of moisture and temperature. Various research workers, particularly those concerned with the breeding of new varieties, have developed methods of overcoming this dormancy of freshly harvested seed. The object of this paper is to review this work and to describe some recent experiments carried out at Wye College. The methods used can be conveniently considered under three headings:

(*a*) Temperature treatments.
(*b*) Physical treatments.
(*c*) Chemical treatments.

### Review of the Literature

#### (*a*) *Temperature treatments*

Raum (1929) observed that a flush of seedlings generally appeared in the hop fields in early spring. He obtained good germination by sowing freshly harvested seed in moist soil and allowing it to overwinter in the open or in unheated glasshouses. Smith (1939) and Holubinsky (1941) carried out a number of

detailed experiments into the low temperature and moisture requirements of hop seeds. Smith found that a period of refrigeration of moist seeds was effective in breaking dormancy. Some increase in the number which germinated was obtained after periods of temperature as low as —12° C. For maximum germination (about 60% with the varieties tried) he recommended the following method. Seeds were sown on moist paper, given five days incubation at 15-23° C. followed by five weeks refrigeration at 5° C. When seed was returned to 15° C., germination occurred within a period of three weeks. Keller (1953) extended the work of Smith. He omitted the period of incubation prior to the low temperature treatment. In general, he found that while his control seeds in a heated glasshouse failed to give on the average more than 10 per cent. germination, germination rates of the order of 85 per cent. could be obtained from seed sown in moist vermiculite after a period of five or six weeks at 1·7° C. (35° F.). In Britain, Paine (1950) tried the effect of freezing upon the germination rate of seed of the variety Fuggle. He concluded that freezing had no effect on germination. These results appear to conflict with the findings of Smith and Keller. This may be due to the size of the samples taken. Both Smith and Keller used 100 seeds for each treatment. Paine used only five.

(*b*) *Physical treatments*

Bressman (1931) was able to increase the percentage of seed germination by scarification with coarse emery paper. He recommended that this treatment be preceded by a period of ten days at 0° C. Keller (1953) was unable to improve germination either by scarification or mechanical shaking with abrasives when the period of low temperature was omitted. Paine (1950) obtained effective and rapid germination by chipping the hard testa. His method was to remove the operculum with a needle. He emphasized that care must be taken not to damage the underlying radicle of the seed.

(*c*) *Chemical treatments*

Keller (1953) carried out a number of experiments using a wide range of chemicals at varying strengths. These included sulphuric and hydrochloric acids, methyl alcohol, acetone. ether, xylene and ethylene chlorohydrin gas. He concluded that in no case did these chemical treatments stimulate germination. Paine (1950) found that 0·1 per cent. mercuric chloride solution in water had no effect.

## Experimental Work

### (*a*) *Temperature treatment*

In the majority of experiments, seed from two varieties, Fuggle N and Eastwell Goldings, was used. Seed resulting from open pollination was harvested from mature plants growing at Wye College in September, 1957. After cleaning the seed was dry-stored at room temperatures.

Immediately prior to treatment, seeds were soaked for 24 hours; 100 seeds were used for each treatment. These were set out upon moist filter paper in petri dishes.

#### *Experiment 1. Influence of low temperature*

Batches of 100 seeds were placed for successively longer periods in a temperature of 4·4° C. (40° F.). They were then moved to an incubator maintained at 20° C. In order to find out whether the removal of the loose outer seed coat was beneficial a second series of each variety was treated with the outer coat removed. Germination was considered successful when both the radicle and plumule had emerged and the cotyledons had separated.

*Results*

| Weeks at 4·4° C. | Outer seed coat removed % germination | Outer seed coat retained % germination | Control 20° C. % germination |
|---|---|---|---|
| **Seed from Fuggle N** | | | |
| 1 | 0 | 0 | |
| 2 | 12 | 20 | |
| 3 | 80 | 54 | |
| 4 | 83 | 79 | |
| 5 | 90 | 73 | |
| 6 | 80 | 82 | 2 |
| **Seed from Eastwell Golding** | | | |
| 1 | 0 | 0 | |
| 2 | 9 | 3 | |
| 3 | 73 | 57 | |
| 4 | 70 | 83 | |
| 5 | 94 | 91 | |
| 6 | 91 | 87 | 0 |

These results support the American work. Upon moving seeds to the incubator germination was rapid. The majority of seed which

germinated in each treatment did so within two weeks after low temperature treatment. Removal of the loose outer coat surrounding the hard testa did not significantly influence the number which germinated.

*Experiment 2. The influence of low temperature upon the germination of triploid seed*

In the hop breeding programme at Wye College the germination of polyploid seed is important. Experiment 1 was therefore repeated comparing the effect of this treatment upon diploid and triploid seeds from Eastwell Golding.

*Results*

| Weeks at 4·4° C. | Diploid % germination | Triploid % germination | Diploid Control (20° C.) % germination | Triploid Control (20° C.) % germination |
|---|---|---|---|---|
| 1 | 0 | 0 | | |
| 2 | 0 | 4 | | |
| 3 | 64 | 55 | | |
| 4 | 88 | 89 | | |
| 5 | 93 | 97 | | |
| 6 | 85 | 91 | 0 | 0 |

No significant difference between the diploid and triploid seeds was found. The triploid seeds germinated readily after four weeks low temperature treatment. It was noticed that after low temperature treatment the majority of the diploid seeds germinated 24 to 48 hours earlier than the triploid seeds.

*Experiment 3. The influence of low temperature upon germination of seed sown directly into soil*

Seedlings have been needed in successive batches for pathological research work during the winter period. It was necessary to sow the seed direct into soil. To compare the effect of this method with the petri dish technique described above, the following experiment was carried out. Seeds from the variety Fuggle N were pre-soaked for 24 hours then sown in batches of 100 in $5\frac{1}{2}$ in. pots, 1 cm. deep, in a soil mixture of two parts sterilized loam,

one part coarse sand, and one part peat. A second series was set out in petri dishes. Both series were placed in the refrigerator at 4·4 °C. for the requisite treatment period and then placed in the incubator.

*Results*

| Weeks at 4·4° C. | Petri dish % germination | Soil % germination | Control Petri dish (20° C.) % germination | Control Soil (20° C.) % germination |
|---|---|---|---|---|
| 1 | 0 | 0 | | |
| 2 | 4 | 0 | | |
| 3 | 54 | 61 | | |
| 4 | 83 | 88 | | |
| 5 | 87 | 93 | | |
| 6 | 87 | 88 | 0 | 0 |

Seeds sown in soil were successfully grown on in a heated glasshouse. It can be seen that the seed sown directly into soil germinated as well as those placed in petri dishes.

*Experiment 4. Moisture in relation to the low temperature treatment*

To establish the optimum moisture conditions during the low temperature treatment the following experiment was carried out with seed from Fuggle N.

(*a*) Seed sown on air-dry filter paper. (Dry.)

(*b*) Seed sown on moist filter paper with no free water. (Moist.)

(*c*) Seed soaked for 24 hours prior to treatment and sown on thoroughly wet filter paper; free water maintained in petri dish. (Wet—pre-soaked.)

(*d*) Seed not soaked but otherwise as for (*c*). (Wet—not pre-soaked.)

*Results*

| Weeks at 4·4° C. | (*a*) Dry % germination | (*b*) Moist % germination | (*c*) Wet—presoaked % germination | (*d*) Wet—not presoaked % germination |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 1 | 0 | 2 | 0 |
| 3 | 0 | 39 | 43 | 33 |
| 4 | 7 | 57 | 84 | 74 |
| 5 | 0 | 65 | 89 | 81 |
| 6 | 3 | 64 | 89 | 83 |

These results emphasize the importance of a low water tension during the cold treatment to obtain maximum germination.

*Summary—Low temperature treatments.*

In the series of experiments described above the following method gave optimum results:

(*a*) Pre-soak the seed for 24 hours immediately prior to treatment.
(*b*) Sow on to wet filter paper or direct into moist soil. Nothing was gained by removing the loose outer seed coat.
(*c*) Place in a refrigerator at 4·4° C. for five to six weeks.
(*d*) Removal to an incubator at 20° C. or to a heated glasshouse (minimum temperature 10° C.). This method resulted in 70-85 per cent. of the seeds germinating within four weeks of removal to the incubator.

(*b*) *Physical treatments*

The disadvantage of the low temperature treatment lies in the fact that at least seven weeks must lapse before germination is complete for the majority of seeds. The method of chipping described by Paine results in good germination within ten days to three weeks without low temperature treatment. Its disadvantage lies in the fact that some care is needed in chipping each seed and considerable labour is involved where large numbers of seeds have to be treated. Its effectiveness is shown by the following experiment.

*Experiment 5. Effect of chipping*

| | Seeds from Fuggle N | | Seeds from E. Golding | |
|---|---|---|---|---|
| Weeks at 20° C. | unchipped % germination | chipped % germination | unchipped % germination | chipped % germination |
| 1 | 0 | 4 | 0 | 17 |
| 2 | 1 | 58 | 0 | 44 |
| 3 | 0 | 22 | 0 | 11 |
| Total | 1 | 84 | 0 | 72 |

*Experiment 6. Scarification*

Where large numbers of seed are available and a rapid method of obtaining a sample is required the following technique may be

useful. Seed was pre-soaked for 24 hours. It was then spread out on a wooden surface and rubbed lightly with a No. 2 (fine) sand-paper sheet fastened round a wooden board. The seed was rubbed a number of times. As far as possible only the pressure of the weight of the wood was applied. After scarification the seed was incubated on moist filter paper in an incubator at 20° C.

*Results*

| Rubbed | Seeds from Eastwell Golding % germination |
|---|---|
| × 50 | 7 |
| ×100 | 19 |
| ×150 | 64 |
| ×200 | 13 |

*Summary Physical treatments*

Where seed is limited and rapid germination is required the method of chipping described by Paine (1950) is very effective. The cruder method of scarification with sand-paper may be useful where seed is plentiful.

(*c*) *Chemical treatments*

The chemical treatments were in all cases applied to seeds from the variety Fuggle N and are discussed under three headings:

Miscellaneous substances which have been used empirically and effectively on seeds of other plants (Expt. 7.)

Metal-complexing compounds known to affect enzymes which might be concerned with seed dormancy. (Expt. 8.)

Chemicals expected to have a physical effect on the seed coat—i.e. sulphuric acid. (Expts. 9, 10 and 11.)

*Experiment 7*

Initially a group of chemical treatments such as had been used effectively with seeds of other plants (Toole *et al.*, 1956) were given a preliminary examination. In most cases the mode of action is not known.

For each treatment 50 seeds were taken and the treatments were: gibberellic acid 50 p.p.m., 100 p.p.m. and 4,000 p.p.m., malic acid 0·5%, potassium nitrate 0·2%, and thiourea 0·5%, 2·0% and 5·0%. For each treatment duplicates were prepared,

in one of which seeds were washed thoroughly with water after steeping for 15 minutes, and in the other the seeds were maintained in contact with the steeping solution for the whole period of incubation.

After incubation for three weeks, only the treatment with thiourea maintained in contact with the seeds had had any effect, and this was slight (7-10 per cent.). At the conclusion of the experiment non-germinated seeds were shown to be viable in all treatments since they germinated readily after chipping.

*Experiment 8.*

As a result of suggestions made in connection with barley dormancy, that enzymes such as peroxidase might play a part in preventing germination (Pollock and Kirsop, 1956) a series of treatments by metal-complexing compounds was applied. These compounds would destroy or inhibit enzymes containing certain metals and could suggest a definite basis for dormancy.

These treatments, applied in a similar way to the previous ones, were: hydrogen sulphide—saturated aqueous solution, bis-cyclohexanoneoxalyldihydrazone, 0·05% (in ammonium citrate buffer pH 7) dimethylglyoxime, 0·1%, ethylenediamine tetracetic acid (sodium salt) 1%.

The seeds remained viable in every case, as was shown by subsequent chipping, but none of the treatments had any effect on germination and the conclusion must be drawn that either metal-enzyme systems are not involved in dormancy in hop seeds or else the chemicals used did not penetrate the seed coat.

*Experiment 9.*

A third series of treatments were carried out using sulphuric acid. A preliminary test showed some breaking of dormancy when concentrated acid was applied for a short time.

Prolonged treatment with weak acid showed some breaking of dormancy but in general killed the embryo. The effect of the strong acid was comparable to chipping or scarification methods and could be considered as merely a chemical method of removing the seed coat. That the outer seed coat slowed down this process somewhat is shown by the lower germination and the longer treatment needed to give maximum germination. In both cases the 30 minutes treatment was sufficient to kill the embryo.

*Results*

| Conc. of sulphuric acid | Time of steeping | % germination | |
|---|---|---|---|
| | | outer coats on | outer coats off |
| 0·05% | throughout incubation | 0 | 0 |
| 0·5% | ,, | 2 (died later) | 0 |
| conc. | 3 min. | – | 7 |
| ,, | 5 min. | 4 | 41 |
| ,, | 15 min. | 9 | 19 |
| ,, | 30 min. | 0 | 0 |

*Experiment 10.*

Even when germination did occur following treatment with sulphuric acid, some damage to the root tip was always evident. A further series of treatments using a finer gradation of steeping times was carried out and followed by washing in running water for 24 hours. All seeds (outer coats off) were treated with concentrated acid and washed for 24 hours.

*Results*

| Time of steeping | % germination |
|---|---|
| 1 min. | 0 |
| 3 ,, | 0 |
| 6 ,, | 12 |
| 9 ,, | 24 |
| 15 ,, | 7 |

*Experiment 11.*

Although the 9 minutes steeping in sulphuric acid was shown to give optimum germination for this type of treatment, the number germinating was still small and many seedlings showed root tip damage.

A third series of treatments was designed to reduce the damage and promote greater germination by superimposing the concentrated sulphuric acid treatment on one of the physical treatments, which had already been shown to be partly effective.

*Results*

| Treatment | % germination |
|---|---|
| 10 min. in conc. sulphuric acid then soaked in sodium bicarbonate solution 24 hours .. .. .. | 24 |
| 10 min. in conc. sulphuric acid then washed in water .. | 28 |
| 10 min. in conc. sulphuric acid then soaked in 2% thiourea | 28 |
| 10 min. in conc. sulphuric acid + 1 week at 4·4° C. .. | 26 (0 without acid) |
| 10 min. in conc. sulphuric acid + 2 weeks at 4·4° C. .. | 56 (7 without acid) |

*Summary—Chemical treatments*

Chemical treatments other than sulphuric acid had no effect on germination except that with thiourea treatments at all concentrations a very small percentage of germination was observed.

Concentrated sulphuric acid treatment had an effect which could probably be attributed mainly to the removal of the inner seed coat and is therefore comparable to chipping or scarification.

## Conclusion

Low temperature treatment was effective in breaking the dormancy of the majority of seed, resulting in a high percentage of germination. This method is to be preferred where large quantities of seed are involved. The low temperature treatment must, however, be given for several weeks. For more rapid results chipping the individual seeds or scarification as described, are effective.

Treatment with chemicals was disappointing. Concentrated sulphuric acid was fairly successful but usually resulted in some damage to the root tip. Other chemical treatments tried either had no apparent effect upon germination or so slight an effect as to be of little practical use.

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# APPENDIX I

## THE CHALLENGE CUPS FOR THE NEW VARIETIES OF HOPS

F. H. Beard

The fourteenth annual exhibition of New Varieties of Hops was held, under the auspices of the Institute of Brewing, on November 26th and 27th, 1957, at 15 Southwark Street, London, S.E.1. As in previous years the show was organized by Messrs. Wigan, Richardson & Co., who added considerable interest to the exhibition by their display of past and present tools used in the hop trade.

Three challenge cups are competed for as follows:

(1) The Brewers' Cup, for hops intended as substitutes for American hops; this cup was presented in 1944 by Messrs. Barclay, Perkins, Messrs. Guinness and Messrs. Whitbread.

(2) The Growers' Cup, for hops intended to augment English commercial varieties; this cup was presented in 1946 by the Association of Growers of New Varieties of Hops.

(3) The Hop Merchants' Association's Cup; presented in 1949 by this Association for new varieties certified as showing tolerance to *Verticillium* Wilt.

The judges were Messrs. John Morris, Dudley Le May, and A. E. Quin with Col. F. N. Richardson acting as Chairman. There was a record entry of 86 samples and a list of entries, together with the analyses carried out at Wye College by Mr. E. W. Weston, is given below in Tables 1-3.

The Brewers' Cup (Table 1) was awarded to Mr. W. H. Hoad for a sample of Bullion (Q43) with an analysis of 9·12 per cent. alpha resin and 12·33 per cent. beta resins; the second place was given to the same variety grown by Furnace Farms Ltd. with an analysis of 8·07 per cent. alpha resin and 10·84 per cent. beta resins. Placed third was another sample of Bullion from the Guinness farms at Bodiam. The general level of the analyses shows that while 1957 was better than 1956 it was still a poor year for resins. In 1956 and 1957 the best analyses were respectively 7·8 and 9·1 per cent. alpha resin, but in 1955 four growths had over 10 per cent. alpha

TABLE I

ENTRIES FOR BREWERS' CHALLENGE CUP 1957

| Variety and Grower | Parish | Hops moisture-free | |
|---|---|---|---|
| | | alpha acid % | beta fraction % |
| *Bullion Hop* (Q43) | | | |
| *W. H. Hoad .. .. | Salehurst, Sussex | 9·12 | 12·33 |
| W. D. Hukins .. .. | Tenterden, Kent | 8·36 | 11·25 |
| †Furnace Farms Ltd. .. | Lamberhurst, Kent | 8·07 | 10·84 |
| Wm. Alexander Ltd. .. | Eynsford, Kent | 7·90 | 11·14 |
| E. M. Gorst .. .. .. | Brenchley, Kent | 7·89 | 10·70 |
| Wm. Alexander Ltd. .. | Eynsford, Kent | 7·86 | 11·36 |
| ‡Guinness Hop Farms Ltd. .. | Bodiam, Sussex | 7·70 | 11·22 |
| John Turner .. .. | Bosbury, Hereford | 7·59 | 11·40 |
| B. P. Tompsett .. .. | Bosbury, Hereford | 7·13 | 11·80 |
| R. D. Wickham .. .. | Brenchley, Kent | 7·09 | 11·05 |
| Tassell Bros. .. .. | Ulcombe, Kent | 6·89 | 10·51 |
| J. Nott .. .. .. | Tenbury, Worcs. | 6·83 | 10·87 |
| Ditton Court Farm Ltd. .. | Ditton, Kent | 6·83 | 9·21 |
| E. J. Williams .. .. | Hereford | 6·39 | 10·08 |
| Lower Hope Farms Ltd. .. | Ullingswick, Hereford | 6·25 | 10·77 |
| J. A. Worley .. .. | Chart Sutton, Kent | 6·21 | 9·79 |
| E. J. Williams .. .. | Hereford | 6·16 | 10·25 |
| T. D. & H. Harris .. .. | Tonbridge, Kent | 6·05 | 8·73 |
| Guinness Hop Farns Ltd. .. | Teynham, Kent | 5·96 | 9·46 |
| J. F. Bomford .. .. | Fladbury, Worcs. | 5·89 | 10·06 |
| G. Nott & Co. Ltd. .. | Eardiston, Worcs. | 5·76 | 8·62 |
| *Brewer's Gold* (C9a) | | | |
| Wm. Skinner & Son .. .. | East Sutton, Kent | 7·66 | 10·16 |
| Guinness Hop Farms Ltd. .. | Teynham, Kent | 7·06 | 10·76 |
| E. L. Worsfold .. .. | East Sutton, Kent | 6·59 | 10·02 |
| *Copper Hop* (OK40) | | | |
| J. F. Bomford .. .. | Fladbury, Worcs. | 6·85 | 9·44 |
| *College Cluster* (N15 bis) | | | |
| Guinness Hop Farms Ltd. .. | Teynham, Kent | 5·80 | 7·64 |

* Awarded cup. † Placed second. ‡ Placed third.

resin. Competition for this cup is now almost entirely confined to samples of Bullion; this season there were only 3 growths of Brewer's Gold and single entries of Copper Hop and College Cluster.

The Growers' Cup (Table 2) was again awarded to Messrs. A. & K. J. Amos for their growth of Northern Brewer which had an analysis of 7·34 per cent. alpha resin and 9·35 per cent. beta resins.

TABLE 2

ENTRIES FOR GROWERS' CHALLENGE CUP 1957

| Variety and Grower | Parish | Hops moisture-free | |
|---|---|---|---|
| | | alpha acid % | beta fraction % |
| *Northern Brewer* (WFB135) | | | |
| J. F. Bomford | Fladbury, Worcs. | 9·49 | 10·24 |
| B. P. Tompsett | Brenchley, Kent | 9·41 | 9·76 |
| Ashdown Farm Ltd. | Horsmonden, Kent | 8·54 | 9·37 |
| J. & P. Day Ltd. | West Farleigh, Kent | 8·17 | 9·60 |
| J. A. Worley | Yalding, Kent | 8·03 | 9·47 |
| J. & P. Day Ltd. | West Farleigh, Kent | 7·95 | 9·68 |
| Whitbread & Co. Ltd. | Beltring, Kent | 7·84 | 9·62 |
| J. & P. Day Ltd. | West Farleigh, Kent | 7·74 | 8·92 |
| Wm. Alexander Ltd. | Eynsford, Kent | 7·74 | 9·31 |
| J. Nott | Tenbury, Worcs. | 7·67 | 9·49 |
| John Turner | Bosbury, Hereford | 7·60 | 10·02 |
| *A. & K. J. Amos | Wye, Kent | 7·34 | 9·35 |
| W. H. Tooby & Son | Chadley, Worcs. | 7·29 | 8·83 |
| J. Dinnis & Son | Shoreham, Kent | 7·17 | 8·57 |
| Wm. Skinner & Son | East Sutton, Kent | 7·09 | 10·71 |
| Tassell Bros. | Ulcombe, Kent | 7·08 | 8·90 |
| W. H. Hoad | Salehurst, Sussex | 6·92 | 9·73 |
| H. Veall | Capel, Kent | 6·87 | 9·71 |
| J. A. Worley | Chart Sutton, Kent | 5·90 | 9·36 |
| E. L. Worsfold | East Sutton, Kent | 5·85 | 8·66 |
| G. Nott & Co. Ltd. | Eardiston, Worcs. | 5·74 | 9·09 |
| T. D. & H. Harris Ltd. | Tonbridge, Kent | 5·70 | 8·26 |
| Guinness Hop Farms Ltd. | Teynham, Kent | 5·47 | 8·91 |
| *Pride of Kent* (170a) | | | |
| H. Veall | Capel, Kent | 7·37 | 12·71 |
| †J. F. Bomford | Fladbury, Worcs. | 6·44 | 12·68 |
| W. D. Hukins | Tenterden, Kent | 6·24 | 12·26 |
| ‡A. & K. J. Amos | Wye, Kent | 6·16 | 12·40 |
| *Early Promise* (X35) | | | |
| Castlemain Farms Ltd. | Horsmonden, Kent | 6·24 | 7·92 |
| *John Ford* (WFA90) | | | |
| J. F. Bomford | Fladbury, Worcs. | 5·49 | 11·77 |
| *Brewers' Favourite* (OP21) | | | |
| W. A. Large & Sons | Tonbridge, Kent | 5·24 | 9·66 |
| *OQ*14 | | | |
| A. & K. J. Amos | Wye, Kent | 6·01 | 9·44 |
| *ON*78 | | | |
| J. F. Bomford | Fladbury, Worcs. | 5·44 | 8·38 |
| *OF*27 | | | |
| J. Nott | Tenbury, Worcs. | 5·22 | 10·55 |
| *AGG*8 | | | |
| Guinness Hop Farms Ltd. | Teynham, Kent | 4·35 | 8·50 |

* Awarded cup. † Placed second ‡ Placed third.

TABLE 3

ENTRIES FOR HOP MERCHANTS' ASSOCIATION'S CUP

| Variety and Grower | Parish | Hops moisture-free | |
|---|---|---|---|
| | | alpha acid % | beta fraction % |
| *Whitbread's Golding Variety* (1147) | | | |
| D. H. J. Britcher .. .. | Marden, Kent | 6·00 | 7·85 |
| Whitbread & Co. Ltd. .. | Beltring, Kent | 5·55 | 7·95 |
| E. M. Gorst .. .. .. | Brenchley, Kent | 5·45 | 8·20 |
| C. E. & W. S. Millson .. | Goudhurst, Kent | 5·45 | 7·96 |
| G. A. & S. G. Calcutt .. | Goudhurst, Kent | 5·27 | 8·22 |
| C. E. & W. S. Millson .. | Goudhurst, Kent | 5·27 | 7·47 |
| J. & P. Day Ltd. .. .. | West Farleigh, Kent | 5·01 | 6·77 |
| J. & P. Day Ltd. .. .. | West Farleigh, Kent | 4·89 | 7·59 |
| T. D. & H. Harris Ltd. .. | Tonbridge, Kent | 4·84 | 7·32 |
| J. & P. Day Ltd. .. .. | West Farleigh, Kent | 4·75 | 7·52 |
| J. A. Worley .. .. | Yalding, Kent | 3·87 | 7·16 |
| J. A. Worley .. .. | Yalding, Kent | 3·38 | 7·38 |
| *Bramling Cross* (OT48) .. | | | |
| *D. H. J. Britcher .. .. | Marden, Kent | 5·72 | 8·44 |
| J. & P. Day Ltd. .. .. | West Farleigh, Kent | 5·27 | 7·74 |
| †J. & P. Day Ltd. .. .. | West Farleigh, Kent | 5·23 | 7·87 |
| ‡C. E. & W. S. Millson .. | Goudhurst, Kent | 5·12 | 8·56 |
| Brian H. Day Ltd. .. | Marden, Kent | 4·98 | 7·84 |
| J. & P. Day Ltd. .. .. | West Farleigh, Kent | 4·98 | 7·53 |
| J. A. Worley .. .. | Chart Sutton, Kent | 4·58 | 7·29 |
| J. A. Worley .. .. | Yalding, Kent | 3·97 | 7·92 |
| *Keyworth's Midseason* (OR55) | | | |
| Guinness Hop Farms Ltd. .. | Bodiam, Sussex | 6·22 | 7·88 |
| T. D. & H. Harris Ltd. .. | Tonbridge, Kent | 6·14 | 8·43 |
| *OZ97a* | | | |
| T. D. & H. Harris Ltd. .. | Tonbridge, Kent | 4·77 | 9·04 |
| Brian H. Day Ltd. .. | Marden, Kent | 4·06 | 10·22 |
| D1(E.M.R.S.) | | | |
| Brian H. Day Ltd. .. | Marden, Kent | 4·19 | 8·44 |
| *J2* (E.M.R.S.) | | | |
| Whitbread & Co. Ltd. .. | Beltring, Kent | 3·72 | 6·75 |

* Awarded cup. † Placed second. ‡ Placed third.

A growth of Pride of Kent from Capt. J. F. Bomford obtained second place. This sample had an analysis of 6·44 per cent. alpha resin and 12·68 per cent. beta resins. Third place was taken by a sample of Pride of Kent, from Messrs. A. & K. J. Amos with an analysis of 6·16 per cent. alpha resin and 12·40 per cent. beta resins. Although the bulk of the entries in this class were Northern Brewer (23 samples) the four samples of Pride of Kent provided very keen competition as is shown by the fact that second and third places went to this variety. Single sample entries were made of seven other varieties, including such early introductions as Brewer's Favourite and Early Promise, first named in 1934 and 1937 respectively. The analyses of this season's samples demonstrate clearly the inherent tendency of Pride of Kent to produce a high proportion of beta resins. It is also interesting to note that the winning sample of Northern Brewer had only a moderate analysis, eleven samples having a higher and eleven a lower alpha resin content.

In the competition for the Hop Merchants' Association's Cup all three of the placed samples were of the variety Bramling Cross. Mr. D. H. J. Britcher secured first place with a sample giving an analysis of 5·72 per cent. alpha resin and 8·44 per cent. beta resins. A sample from Messrs. J. & P. Day Ltd. having 5·23 per cent. alpha resin and 7·87 per cent. beta resins took the second place, while Messrs. C. E. and W. S. Millson's sample with an analysis of 5·12 per cent. alpha resin and 8·56 per cent. beta resins was placed third.

Entries for this competition were a record, the 26 samples being an increase of ten over 1956. Competition in the main is between Whitbread's Golding Variety and Bramling Cross. The two samples of OZ97a were definitely not of the standard that could be expected of the variety, but it must be noted that the plantings of this variety are still on a small scale and that there are inherent difficulties in the growing and drying of small lots of hops. It may, therefore, be expected that as the size of the OZ97a plantings increase so will the quality of the samples submitted for competition, as has happened in the case of Bramling Cross.

# APPENDIX II

## FLUCTUATIONS IN HOP CULTIVATION AND CLASSIFICATION OF HOP REGIONS IN SOUTH-EASTERN ENGLAND

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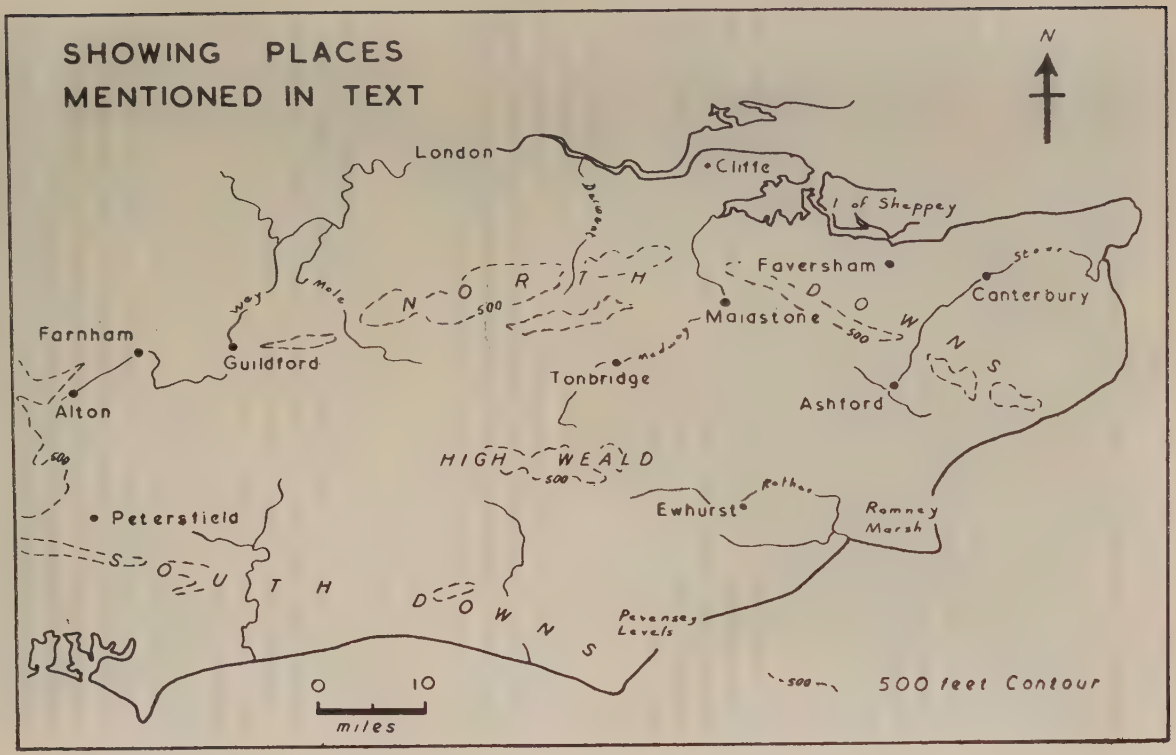
### Introduction

Although covering well under one per cent. of the total area, hops constitute south-eastern England's most distinctive and characteristic crop. To the observer they exhibit not only the present permanent framework of garden or yard—never field—but also vestiges of *former* activity in the numerous disused or converted oast-houses, in over-developed hedgerows, once grown as wind-shields but now sheltering fields of corn, in copses formerly closely related to gardens to provide hop poles, and in "wild" hops, most of which represent escapes from past cultivation. By a study of parish acreages during the last 150 years it is possible to follow the fluctuations in hop-growing in south-eastern England and to attempt a classification into regions.

After a gradual increase in the early 19th century the four south-eastern counties by 1835 possessed 37,000 acres of hops, which after 1862 rose sharply to a peak of 63,000 in 1878, followed by a rapid decline to under 11,000 in 1932, rising again slowly to a moderate 13,000 acres today. The cause of the rising acreage was, firstly, the policy of farmers to maintain a large area in hops as their only safeguard against the crop's widely fluctuating yields (see below), and the huge profits which could accrue from a successful

| *Year* | *Acreage* | *Production (cwt.)* |
|---|---|---|
| 1853 .. .. | 49,367 | 283,920 |
| 1854 .. .. | 53,825 | 88,188 |
| 1855 .. .. | 57,757 | 743,047 |

harvest in a season of widespread disease. An old hop grower's prayer is said to have run "that he may have a good crop of hops, and his neighbour none". Young (1793) called hops "the gambling of


SHOWING PLACES
MENTIONED IN TEXT
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London
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I. of Sheppey
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Canterbury
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Maidstone
DOWNS
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Farnham
Guildford
Medway
Tonbridge
Ashford
Alton
500
HIGH WEALD
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Petersfield
Rother
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Romney Marsh
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Fig. 1.

farmers", and Buckland (1845) reported to the Royal Agricultural Society in similar terms—"a lottery". Secondly, the abolition in 1862 of the excise duty on hops, averaging £7 per year for each acre, was the signal for the Sussex and Kentish Wealden farmers in particular, to plant up gardens of easily grown hops of a coarse variety in areas where formerly a low return made their cultivation economically precarious. However, a culmination of several circumstances soon exposed this feverish activity as unwarranted and unsound, and a precipitous decline in acreage has been followed by a stabilization under the quota system of the Hops Marketing Board at less than a quarter of the 1878 peak. Figs. 2 and 3 show the extent of the decline, the causes of which may be briefly summarized.

The 1862 Act abolished not only the hop excise duty but also the *import* duty, which, coinciding with a change of taste by English brewers towards the use of up to a third of foreign hops, introduced foreign competition and removed the attractive gambling element in home production. In addition, the yield per acre has doubled since the golden era around 1880, and harvest reliability has increased with improved control over pests and diseases and the higher standard of cultivation generally. Furthermore, fewer hops are used today for flavouring and preserving beer; for not only has consumption declined, but, more important, the public's taste has shifted from heavy to lighter, sweeter varieties of beer. Before 1870 certain strong beers received up to 6 lb. of hops per standard barrel; today the hopping rate is around 1-1½ lb. per standard barrel.

### 1878 Distribution

The most striking point concerning the distribution of hops in 1878 (Fig. 2) is the seemingly indiscriminate location of hop gardens over the geological formations in the eastern part of the region, and yet almost complete lack of development on the Wealden clays and Lower Greensand formation of West Surrey and Sussex. Further points to be noted are the extremely dense area of growth around Maidstone; a less dense but larger area of hops on the Wealden clays and sands extending into East Sussex; a detached region in the extreme west, and a partially detached zone north of the Downs in Kent. However, although this was the era of greatest expansion, and much planting was indiscriminate, certain correlations may be drawn with the geological formations.

The dense area around Maidstone, known as the "Mother of Hop Grounds" before Defoe's time, may be correlated with the

fertile loams weathered from the Hythe Beds or formed as a result of downwash from the Lower Greensand, and the Medway alluvium. Not unimportant was the area's early and easy access to London both for export of produce and import of London dung by way of the Medway. Even the extensive distribution on Wealden clay is not one simple piece of farmers' indiscriminate folly. From Fig. 2 it is possible to distinguish a zone of denser cultivation around the Medway Valley on alluvial loams and gravels. Elsewhere similar soils of the Medway tributaries, or downwash from the Hastings Beds were attracting influences. "When therefore you see hops in the Weald, it is on the side of some hill, where there is sand or stone at bottom, and not where there is real clay beneath" observed Cobbett (1830). The zone in North Kent, roughly following Watling Street, is again influenced by fertile brick-earths and loams of Thanet Beds and lower North Downs. Westwards the Surrey-Hampshire region may be correlated with the Wey Valley and its Upper Greensand and Gault outcrops, particularly the "malm" soil developed on the former and enriched by downwash from the chalk, a soil which according to Gilbert White (1789) is "neither fit for pasture nor for the plough, but kindly for hops".

Closer study reveals more detailed correlations which seem evident from the map—the presence of hops in the Derwent valley, or in the valley of the Rother and its two tributaries, the Tillingham and Brede, or in the controlling influence exerted by the North Downs and High Weald. The more irregular distribution in the High Weald of Sussex is occasioned by the dissected nature of the relief, with hop gardens ignoring plateau tops for the lower slopes and bottoms of larger valleys. But why no development in the lower, western part of the Weald?

Besides this last area's early relative isolation from the eastern nucleus, and from London with its supplies of dung and market for hops, there exist "considerable differences" (Wooldridge and Goldring, 1953) in the general soil texture between east and west. The hop plant prefers a sheltered location with a deep loam soil and plenty of moisture, but no waterlogging, in the subsoil; such conditions are less frequently encountered westwards. In the east the Weald Clays are notably silty soils; the clay content is generally under 20 per cent. being only half the silt content. Westwards there is an increase in number and thickness of the sandstone and siltstone horizons, providing an almost completely impermeable subsoil. The Lower Greensand formation also changes character; the Hythe Beds, often well-balanced sandy loams in Kent and East Sussex, with other

beds in the formation (notably Folkestone Beds), become progressively less fertile westwards to provide sandy heathlands, in places rising well above a safe limit for hop cultivation.

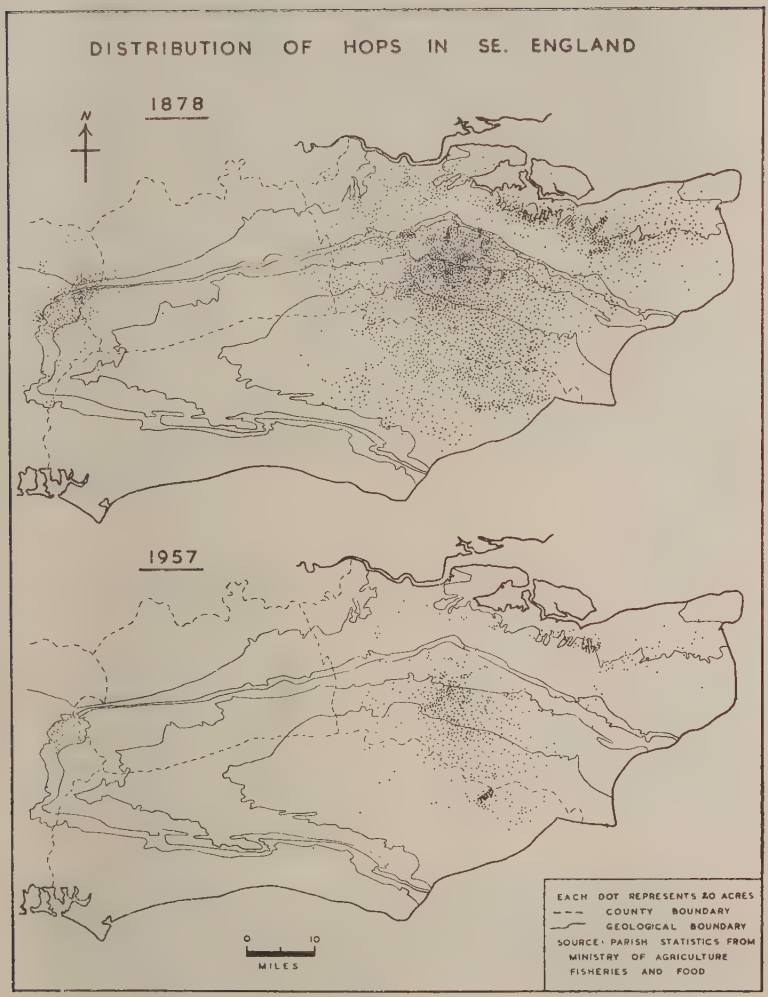
### Today's Picture

Today's picture (Fig. 2) shows that even the *main* centres of production in 1957 only possess densities equivalent to many of the *marginal* areas of 1878. But while areas of greatest coverage in 1878 have suffered the greatest absolute loss, marginal areas have experienced the greatest percentage decline—often the whole acreage. Hops have disappeared from exposed heights and damp lowlands. The North Downs have assumed a dominant role as a barrier between the north and mid-Kent areas, the West Surrey and Hampshire region has contracted to within the Upper Greensand-Gault formation, while in Sussex hops have migrated from the higher parts of the High Weald towards the Kentish border. Similarly, hop cultivation has ceased on Cliffe Marshes, Isle of Sheppey, Romney Marsh and Pevensey Level where exposure to wind and high water tables must have proved detrimental to successful growth of the crop.

If hop growing was once a lottery, it is today a specialized industry, most successful where most specialized, gradually becoming the domain of the large grower. Since 1930 the number of growers has fallen by a third and the average holding increased from 15 to 23 acres. Several large brewer-growers have given a lead in this trend, having accounted for a quarter of the national acreage increase since 1932. Two parishes of diverse fortunes will serve as an example of their potential influence. While surrounding areas have declined or disappeared, the hop acreage of Ewhurst (Sussex) has increased since 1932 by 500 acres (400 above the 1878 figure) and now constitutes 40 per cent. of the county's total acreage. Conversely, the parish of Farnham with over 1,500 acres in 1878 has only 45 acres in 1957, while disused oasts and four silent breweries are encompassed by the town's modern expansion.

### Hop Regions

If to the distributions of 1878 and 1957 one adds pictures for 1835, which is representative of a year before the post-1862 rise, and for 1932, the year of greatest contraction and of the creation of the Hops Marketing Board introducing the modern era,


DISTRIBUTION OF HOPS IN SE. ENGLAND
N
1878
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0 10
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EACH DOT REPRESENTS 20 ACRES
COUNTY BOUNDARY
GEOLOGICAL BOUNDARY
SOURCE: PARISH STATISTICS FROM MINISTRY OF AGRICULTURE FISHERIES AND FOOD

FIG. 2.

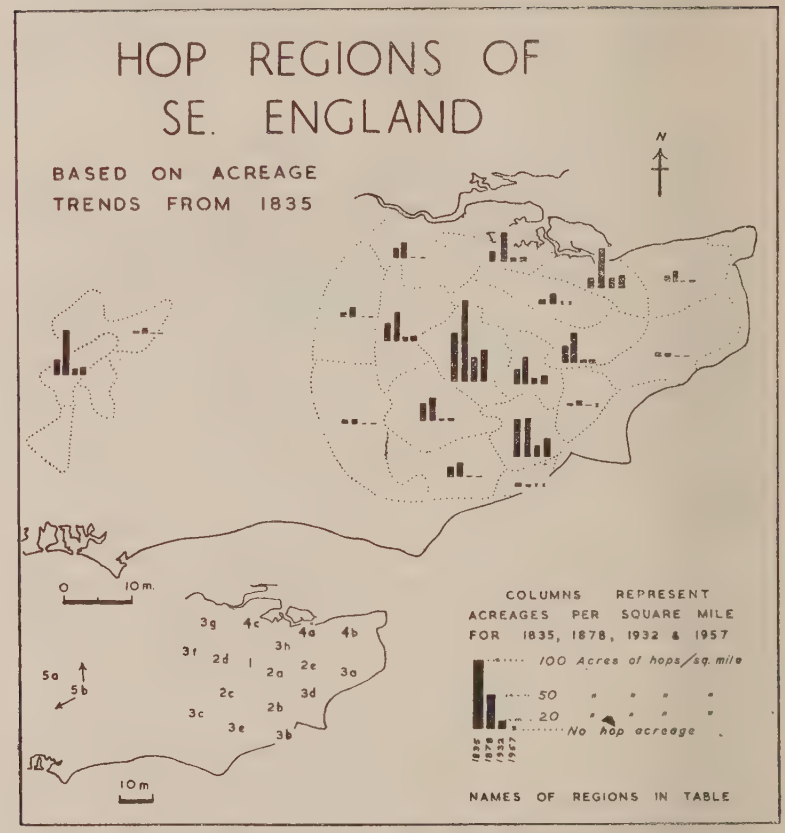


FIG. 3.

it is possible to attempt a classification of hop regions in south-eastern England based on acreage densities for these four representative years. Fig. 3 shows the resultant hop regions, and Table 1 the acreage densities.

Three systems emerge—the Wealden System, a centre around Faversham on the North Kent loam belt, and a Farnham-Alton System.

WEALDEN SYSTEM

The Mid-Kent Wealden Core (Region No. 1), situated on alluvial loams, soils derived from Hythe beds or lower parts of Hastings beds, has always been the greatest and densest area of hop production, experiencing also the most violent fluctuations. Today's high density is still below the 1835 and only a third of the 1878 era when almost one acre in five was given to hop cultivation. Contiguous with the Core are five regions intermediate both in position and characteristics, succeeded in turn by an outer, or marginal, ring.

Next to the Core, the Inner Ring has always possessed the greatest acreage density and shown wide fluctuations. Local variations form the basis for the five-fold subdivision. Region 2a conforms closest to a duplication of the Core at a third of the latter's importance; 2b shows a remarkably high and stable density till 1878, with a strong modern recovery due largely to the activity of an important brewer-grower in Bodiam, Northiam and Ewhurst; 2c is today the least important with surviving activity near the Kentish border; 2d and 2e, extending over varied geological formations, enjoyed a large rise till 1878, but cultivation has since contracted to more selective locations.

TABLE 1

ACREAGE DENSITY OF HOP REGIONS

| Hop region | | Acres per square mile | | | |
|---|---|---|---|---|---|
| No. | Name | 1835 | 1878 | 1932 | 1957 |
| 1 | Mid-Kent Wealden Core .. .. | 71·4 | 120·5 | 36·1 | 46·1 |
| 2a | E. Kent Mid-Weald .. .. | 22·2 | 39·9 | 8·4 | 10·8 |
| 2b | Rother Region .. .. .. | 54·5 | 55·1 | 14·6 | 24·2 |
| 2c | Sussex Inner High Weald .. .. | 26·9 | 33·2 | 2·7 | 3·4 |
| 2d | W. Kent Region .. .. .. | 27·3 | 41·6 | 6·4 | 7·9 |
| 2e | Medway-Stour (Greensand Ridge) | 27·7 | 45·7 | 3·9 | 4·6 |
| 3a | N. Downs Coastal Region .. .. | 6·4 | 5·7 | 0·1 | 0·1 |
| 3b | Sussex Coastal Region .. .. | 6·0 | 2·7 | — | — |
| 3c | Sussex Outer High Weald .. .. | 6·9 | 6·3 | 0·3 | 0·3 |
| 3d | S. Kent Region .. .. .. | 1·4 | 7·1 | 0·1 | — |
| 3e | S. Sussex (Ashdown Ridge) .. | 14·9 | 20·4 | 0·5 | 0·5 |
| 3f | Kent-Surrey Border .. .. | 7·2 | 13·0 | 0·1 | — |
| 3g | N.W. Kent Region .. .. | 11·4 | 20·7 | 0·2 | 0·3 |
| 3h | N. Downs Inner Region .. .. | 5·4 | 14·4 | — | — |
| 4a | N. Kent (Faversham) Loam Belt .. | 16·1 | 58·1 | 14·3 | 18·0 |
| 4b | E. Kent (Canterbury) Loam Belt .. | 9·3 | 14·9 | 2·1 | 2·8 |
| 4c | N.W. Kent Loam Belt .. .. | 13·9 | 41·5 | 4·9 | 5·9 |
| 5a | Alton-Farnham Core .. .. | 22·3 | 66·4 | 9·0 | 11·2 |
| 5b | Bordering Areas .. .. .. | 2·3 | 8·9 | 0·8 | 0·8 |

Further from the centre there occurs a second ring of regions characterized by their marginal location and low average densities. Possessing larger acreages up to the peak era of hop growing, most parishes by 1932 had lost their entire crop, and that which remained has since further declined or is stagnant. Their situations were often high and exposed (e.g. North Downs or Ashdown Ridge) or low and damp (around Isle of Oxney or Pevensey Level), while in the north-west, extension of urban areas and chalk quarrying were adverse factors. The group may be subdivided into three regions of low 1835 densities which were not involved in the 1878 rise (3a, b, c), and those which were (Regions 3d to 3h).

### North Kent System

The second main system (North Kent System) is situated on the fertile North Kent Loam belt between the lower dipslope of the Downs and the sea. Although possessing a lower acreage density than the Inner Ring of the Wealden System, these three regions merit a separate ranking on account of their geographical separation at all stages of development from the first system (even 1878—see Fig. 2), and on account of their distinctive pattern of fluctuation—greatest percentage increase up to 1878 and a strong modern recovery. The core (4a) has a 1957 density well above the 1835 figure, and shows a persistently higher density than either 4b (area of least importance and most scattered cultivation) or 4c.

### Alton-Farnham System

The third system is situated in East Hampshire and extreme West Surrey, separated by at least 30 miles from the first two described. The core (5a) shows a trebling of acreage density up to 1878, recovering slightly today after a sharp reversal to a density still only half that of 1835. Alton and Farnham at the extremities have declined, leaving a narrow zone on the middle slopes of the Wey Valley. A discontinuous border region (5b) around the core has likewise contracted from one of indiscriminate activity covering various soil types to a concentration on the rapidly attenuating Gault-Upper Greensand belt stretching towards Guildford, and its wider zone around Petersfield.

### Conclusions

The main conclusions to be drawn from this largely descriptive account are, firstly, that the late-19th-century rise in acreage was

largely speculative, and that there is no likelihood of today's modest figure ever approaching such heights, given present demands. Secondly, hop growing is no longer an attractive lottery for small farmers, but a specialized form of agriculture for the larger, skilled farmer. Thirdly, from the physical point of view there is no reason why hops should not reveal a wider distribution, but with only a steady demand, a rigid quota system, and the expense of erecting new garden frameworks together with all the necessary ancillaries, it is unlikely that the general pattern of present distribution will be substantially altered. Fourthly, the map of hop regions reveals that the present chief areas have remained throughout the period under consideration the main centres of production, and these centres have been most sensitive to any trends in acreage fluctuation. The three main regions are located where most suitable soil conditions occur, while marginal regions, diminishing in importance away from the centres indicated, are often found on unfavourable situations.

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# APPENDIX III

## HOPS FOR LAGER BREWING

R. A. Neve

In the search for new varieties which is constantly going on at Wye, the criterion of quality has normally been the suitability of the hops for brewing conventional English types of beer. Recently, however, interest has been shown in the possibility of producing varieties suitable for lager brewing .This interest has been stimulated by pressure from the Brewers' Society for permission to import increased quantities of foreign hops. These imports are required mainly for the brewing of lager beer for which English varieties are thought to be unsuitable.

Lager beer is of continental origin, and brewers in this country who now produce lager have to compete with continental brews, and have, therefore, to produce a beer which is as close to the original as possible. One way of doing this is to use the same hop varieties as are used in the continental breweries and this necessitates importing foreign hops. The varieties commonly used are Hallertau from Germany, Saaz from Czechoslovakia or Styrian from Yugoslavia.

The quantity of lager brewed in this country is small, but is increasing. The Brewers' Society estimate that in 1945 it formed only 0·5 per cent. of the total production but that now it is between 1·5 per cent. and 2 per cent. of the total. To keep pace with this increase it has been agreed to increase the quantity of hops which may be imported, for use in lager and other special types of beer, from 1,000 cwt. a year to 6,000 cwt. a year. The old limit of 1,000 cwt. has been consistently exceeded over the past four years, the actual figures for imports during each twelve month period ending August 31st being:

| *1953-4* | *1954-5* | *1955-6* | *1956-7* |
|---|---|---|---|
| *cwt.* | *cwt.* | *cwt.* | *cwt.* |
| 1,713 | 5,077 | 4,892 | 10,455 |

In 1956-7 imports represented over 6 per cent. of the English crop consigned to the Hops Marketing Board, though this was partly due to the short fall in the English crop in 1956.

It was against this background of increasing demands for imported hops that the Hops Marketing Board first suggested in November, 1956, that steps might be taken at Wye to breed varieties which would prove suitable for lager brewing. This request had to be considered in relation to existing demands on available facilities, but since large families of Fuggle and Golding parentage are already undergoing selection, there did seem to be some justification for devoting part of the breeding programme to this new project. Further justification for this decision came from the opinion that any hop variety suitable for lager brewing would also be suitable for dry-hopping English types of beer.

Attempts have been made in the past to grow continental varieties in this country but without success. The reason for this failure is not clear; it may have been that the varieties matured too late under English conditions, or it may have been due to the presence of seeds in English-grown hops. It is widely held that seeds in hops are particularly undesirable in lager brewing, partly because they may cause mechanical blockages in brewery flow systems, but mainly because they impart an unpleasant bitterness to the beer. Much of the experience which is quoted in support of the latter disadvantage is inconclusive since comparisons are generally drawn between seeded English varieties and seedless continental varieties, and it is not clear whether the seed or the variety is causing the unwanted flavour. There would, however, appear to be some foundation for the theory since both American and Belgian hop growers have felt it worth while to change over to growing seedless hops in spite of the resulting drop in yield. This has been achieved by eliminating the male plants from the hop gardens and hedgerows to ensure that pollination does not take place. It is unlikely that a similar course would be practicable in this country.

It seems fairly certain that, whatever the effect of seed, lager brewers would be reluctant to accept any English variety which was heavily seeded, and that seedlessness would have to be the first criterion of a potential new variety. The second criterion would have to be a similarity of aroma to the continental types.

The application of polyploidy to the breeding programme at Wye has been discussed previously in the Annual Reports of the Hop Research Department, but the method appears to be especially suitable for the production of lager beer varieties. By breeding triploid seedlings it is possible greatly to reduce seed content, and at the same time retain a great deal of the brewing characteristics of the parental type. Because of the importance of seedlessness,

no other breeding method would offer any promise of success in this particular project.

The first step in the programme was, therefore, to produce tetraploid forms of suitable continental varieties. Three different clones of Hallertau were growing in the Wye variety collection and colchicine treatment of these was started in 1957. Arrangements have been made for the importation of the Saaz variety and it is hoped to have it available for treatment in 1958. It is not yet known how successful the treatment of Hallertau has been, but there may be tetraploid material available for pollination in 1958, in which case the first samples of hops would be available in 1960. A number of years of selection for yield and brewing quality would have to follow before the most suitable seedling could be chosen. A delay of some ten years is inevitable in any hop breeding programme, and this one is unlikely to be an exception. One particular difficulty is likely to be the assessment of brewing quality since no facilities exist in this country at present for small-scale lager brewing. Since there is every reason to suppose that such new varieties could be available at approximately a half to a third of the price of continental hops, it is hoped that brewers will be interested in helping to assess the new seedlings as far as they are able to do so.

The plant breeder is accustomed to looking a long way ahead to the fulfilment of a breeding programme. The grower and consumer are generally impatient and expect new varieties to be available as soon as the need for them arises. Work on the present programme has been started before there is any great demand for lager hops and it is hoped, in consequence, that the delay between demand and supply will be reduced to the minimum.

*Since going to press more detailed information concerning the import of hops has become available.*

*The figure quoted for imports in 1956-57 includes nearly 3,000 cwt. not of Continental origin and not suitable for lager brewing. In 1955-56 some 800 cwt. and in 1954-55 over 100 cwt. were of non-Continental origin.*

# APPENDIX IV

## PHYSIOLOGICAL PROBLEMS OF HOP CULTIVATION

I. H. Williams

### Introduction

The term "crop physiology" can cover a very wide range of problems. A general definition which includes the major aspects would be as follows: the study of the growth and development of a crop plant in relation to the environment and to the genetic constitution of the plant which will govern its response to the environment.

In the present article it is proposed to consider some of the problems of the hop which lie within the scope of this general definition. Before discussing these in detail, it will be worthwhile considering what is meant by "environment", and by "genetic constitution" in this context.

### The Environment and the Plant

Although the environment includes all conditions external to the plant with which it interacts, it is with the influence of the non-living aspects that the physiologist is primarily concerned. These include climatic factors and weather factors and their influence upon both the visible aerial parts of the plant and upon the underground portion—that is, their influence upon soil conditions. By climatic factors, we generally mean the long-term annual changes in light intensity, length of day, temperature, humidity and overall precipitation. The weather factors cover the less consistent day-to-day variations of wind-speed, temperature fluctuations, changing light intensities due to cloud effects, and the incidence of precipitation. To complete the annual growth cycle of the aerial parts and to survive from year to year the hop, as with other perennial plants must be adapted to the climate in two important respects. Firstly it must be able to survive within the range of each climatic factor, that is, for example, the maximum and minimum temperatures which occur annually. Secondly its annual growth cycle must be so regulated that each phase of growth and development, including

vegetative growth, cone bearing, cone ripening and dormancy, occur in time with the seasonal changes in climatic factors so that each phase occurs under the optimum conditions which the environment provides.

This ability of the plant to respond to climatic changes by changes in growth and development thereby remaining in time with the environment is largely a measure of its inherent capacity, or, in other words, its genetic constitution. A well-known example of this type of relationship is the capacity of many species of plant to initiate flowers only when the daylength lies within a certain narrow range.

### Varietal Differences

Since initially any one variety of hops has been propagated vegetatively from a single parent plant the entire clone will have the same genetic constitution. This means that, under a comparable set of cultural and climatic conditions, the growth behaviour of plants of a single variety may be expected to be the same. But any two varieties being derived from different parent stock may be expected to differ in their growth behaviour, even under identical cultural or environmental conditions, since they will differ in their genetic make-up and hence in the range of their responses.

In commercial practice, this problem becomes important to the grower when varietal differences influence ultimate yield, disease resistance or methods of cultivation. Considering only growth behaviour, varieties may show marked differences in time of flowering, of cone development, of length of laterals or of the position of cone bearing laterals on the bine. Since the grower can, by his methods of cultivation, modify to some degree the environmental effects, he can to some extent control the good, or bad, growth form of his varieties. Important methods will include height of wirework, spacing between plants, form and method of training and timing of cultural operations, all of which, to name a few, are under the control of the grower.

In this type of problem, it must be one of the primary long-term aims of the physiologist working with the hop to establish as far as possible to what extent specific aspects of growth and development are varietal, i.e. decided by the genetical constitution of the variety, to what extent they are regulated by specific environmental factors, and finally, to what extent they can be modified by cultural methods.

If experiments indicate an undesirable varietal characteristic is not amenable to cultural control then a variety likely to prove more suitable must be sought. If however, the variety proves amenable in this respect, then the optimum cultural techniques which are likely to give the desired results must be established.

## Some Current Problems

### (*a*) *Machine Picking*

An example of a grower's problem in which this approach may prove useful is found in considering the suitability of different varieties of hop for machine picking. Two qualities are of particular importance, firstly the development of fairly short cone-bearing laterals, secondly a good distribution of cone bearing laterals down the bine so that a tangled "head" is avoided. In considering any particular variety, experiments must be designed to show whether the variety in question is naturally prone to develop long laterals and a tangled "head" or whether a better habit of growth may be obtained by a different cultural treatment. This is only one, rather over-simplified example and there are many more. It is evident that it is important to obtain this type of information, about both established and new varieties, before launching out upon costly alterations such as those involving height of wirework, spacing, or methods of training or culture.

### (*b*) *Food Storage Mechanism*

Another, perhaps more important problem which has arisen with the advent of machine picking is that this method of harvesting generally results in a lower level of yield compared with the older method of handpicking. A number of factors may be involved, but one possible explanation which can be examined experimentally may lie in the method of food storage of the hop. The full story of this process awaits investigation, but the present evidence would support the following hypothesis.

The truly perennial portion of a hop plant comprises the main root system and that portion of the shoot which lies below soil level. This part of the plant, apart from its other functions, appears to act as a food storage organ able to carry a nutrient reserve from one year to the next. Very little is known about the seasonal fluctuations in this food reserve, that is, the period when reserves are accumulated and the period when utilization by the growing plant results in depletion. It is probable that, during the

early part of the growing season, when growth is very rapid, the aerial portions of the hop utilize this reserve material. At some time in the annual growth cycle, as the total leaf area, and therefore the rate of food synthesis increases, this rate of utilization may decline. Since the development of fruiting laterals will make considerable demands upon the available food material it is unlikely that a build-up of food materials in the rootstock will occur until this phase of development is nearing completion. However, as the cones ripen and annual vegetative growth falls off the demand for food material for current development will decline. Since, at this time the plant carries a large leaf area, it is likely that it is during this late period of the year that the food reserves are built up in the below-ground portions of the plant at an increasing rate, to be drawn upon in the following year.

How does this relate to the method of harvesting? In the case of hand-picking, although the bine is pulled down, after the cones have been stripped off, it is left in the field with a good percentage of mature leaves and still attached to the rootstock. After a short time it can be observed that the leaves re-orientate themselves to the light. It seems likely therefore that food reserves will continue to pass down into the rootstock until the overground shoot becomes senescent. This food material will arise both from the continuing activity of the leaves and from any reserves which may be in the stem. If this is so, then this extra reserve material would be reflected in the yield for the following year.

On the other hand, where machine picking is practised, not more than five feet of the stem portion is left attached to the rootstock when harvesting. In addition, because of the current method of stripping during the growing season this stem portion is usually quite bare of leaves or laterals, so that it is incapable of functioning for the remainder of the season.

It is not known how important this post-harvest period may be in relation to yield, and it is too early to offer concrete suggestions which might assist in overcoming this problem. Possibly, if disease control is feasible, it may be of advantage to leave some laterals or parts of laterals, below the point at which the stem is cut, and this approach is being tried.

*(c) Weather Factors*

Leaving aside consideration of the effect of pests, diseases and nutrition, one important effect upon yield will be the "balance" of all the weather factors, good or bad, upon the plant throughout

the season. This influence of the weather comprises the effect of such factors as wind, wet and dry periods, warm and cold spells both of a few days duration and differences between day and night temperatures, of sunshine hours and of cloudy periods. The grower may feel that his experience is such that these aspects do not justify further experimentation. But is this true? To some extent the grower by his methods of husbandry can offset the bad effects of some weather factors. He can give some wind protection, he can irrigate against water deficit, he can avoid frost pockets. But it would be of considerable help to know which weather factors are most damaging as reflected in ultimate yield, and at what stage each factor becomes limiting. This is not really known, and this type of problem is, in fact, one of the most difficult to solve experimentally. How can the influence of specific short term factors of weather, often acting together, be separately assessed in relation to their ultimate effect upon yield? Today there are experimental techniques which will yield more positive answers to these problems, but they would be difficult to discuss within the scope of the present review. They are the special problems of the crop physiologist.

## Conclusions

In this short paper an attempt has been made to show that problems of the growth and development of the hop are to a large extent a measure of the inherited capacity of the variety under consideration, and its interaction with both the long-term climatic factors and short-term weather factors. Both of these are to some degree capable of modification by the methods of cultivation employed by the grower.

But the grower himself cannot be expected to carry out costly field or laboratory experimentation. Nor indeed will field experiments ever yield complete answers to many environmental problems. Increased yields, which must always be the ultimate aim, will be attained by a reassessment of the traditional knowledge, in this respect of great importance, by carefully planned field experimentation and by the use of more experimental techniques involving the use of a controlled environment. The crop physiologist can make a contribution in this work.

# APPENDIX V

## IRRIGATION PROBLEMS AND THE HOP

I. H. Williams

### Introduction

Whilst a few hop growers have considered some form of irrigation worth while, there is very little experimental evidence to support this. In this paper some of the recent work on the effect of irrigation of other crops is described briefly. The possible application of these findings to the hop is discussed.

### Water Needs in Relation to Calculated Transpiration Loss

Penman (1, 2) has developed a method whereby the quantity of water to be applied during the growing season can be calculated, using current meteorological data. This method seeks to maintain the water content in the soil at a level at which it will not be limiting in relation to growth. It has proved to be effective in the case of a number of field crops. It applies, particularly, to green crops which, for the greater part of the growing season, completely cover the soil. With some modification it can be applied to other types of crop. For full details, the literature quoted must be referred to; Penman's method does give some answer to the question "how much to apply?"

### Water Needs in Relation to the Growth and Development of Specific Crops

To find out the optimum water requirements of any specific crop plant at each stage of its growth and development, is more difficult. It requires carefully controlled experiments involving the use of soil tensiometers over a number of years. As yet, this has been worked out for only a few crop plants. Hudson and his co-workers (3, 4) have carried out this type of experiment with two glasshouse crops, the tomato and the lettuce. Both these crops are treated as annuals. He has shown that the stage of the plant's development and the length of time required for development to the harvesting stage are of prime importance in estimating irrigation needs.

It is assumed that at planting time, the soil is at or near to field

capacity (its maximum water holding capacity without loss through drainage).

During the early period of the plant's growth, new roots are developing downwards and outwards from the initial planting area. Even if no irrigation is applied, the roots are consistently growing into fresh volumes of moist soil. During this period of rapid root expansion these crops do not appear to show a marked response to irrigation.

As the plant ages, two major factors influence its water requirements. Firstly the proportionate increase in top growth which results in a rapid increase in the rate of water loss by transpiration. Secondly the rate of root development declines as the plant approaches its maximum rooting capacity. This latter period of development is important because it is the period when many crops produce their yield. At this time the plant may become highly sensitive to a lack of sufficient available water in the soil. Irrigation at this stage is likely to be reflected in increased growth and yield.

With perennial crops, a different set of conditions may be found. Work on top fruit is in progress (Arthey, 5; Goode, 6) but it is still too early for full evaluation. Since plants of this type start the growing season with an established root system at some depth, it is possible that they are not seriously affected by the drying of the upper region of the soil during the early part of the growing season. Conversely, since these plants have a permanent overground shoot system, transpiration may be high once the leaves have expanded in spring, which may lead to an earlier response to irrigation than is the case with annual crops.

## Water Requirement in Relation to the Growth and Development of the Hop

To what extent can this evidence be of use in estimating the irrigation requirements of the hop? In its habit of growth and development, the hop plant has some affinity with both types of plant described above. The root system is perennial but the entire overground portion is of only annual duration. It is possible, therefore, that since the shoot system in the early part of the growing season is small in relation to the root system, little will be gained by irrigation at this time. Also, the soil in which the root system is established will be near to field capacity during this early period. As the growth of the bine proceeds, and as the total leaf area increases, the rate of water uptake will increase. Irrigation may

become increasingly important if maximum growth and yield are to be obtained.

Another aspect must be considered. The annual phases of root development of the hop have not been studied in detail. It is known, however, that during the latter part of the growing season, when the laterals on the bine are developing their cones, considerable root activity accurs. At this time quantities of small feeding roots ramify throughout the upper surface layers of the soil. It is in these upper layers of the soil that the highest nutrient content is likely to be found. This will be unavailable to the plant if considerable drying out has occurred. It is possible that during this period of maximum development, the availability of nutrients in this upper region of the soil is of considerable importance. Irrigation at this time may well result in higher ultimate yields.

These points suggest that with mature plants, it is in the second half of the growing season that a response to irrigation may be expected. Newly planted material on the other hand may well benefit from early irrigation to assist in the establishment of the new root system.

Finally, the rate of application and the periods between the applications must be considered. Most of the work with other crops suggests that the soil should not be allowed to dry out very far before water is applied. Also, the amount applied should be of sufficient quantity to return the whole volume of soil to near to field capacity. The rate of application must depend to some extent upon the soil type and upon cultural practices at the time.

## Experiments on the Effect of Irrigation of Hops

Some experiments are planned at the Guinness Hop Farms Ltd. and will be carried out at Bodiam in 1958 with the kind co-operation of the Guinness staff and using equipment supplied by them.

The treatments will be based upon Penman's method for calculating irrigation requirements together with the experience gained from the work outlined in this paper on other types of plant. It is hoped that they will give some indication of the effect of irrigation during different periods of the plant's growth upon ultimate yield.

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# APPENDIX VI

## THE 1957 HOP SEASON: WEST MIDLAND REGION

G. P. Chater

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The mild dry autumn and early winter enabled normal winter work to be carried out under ideal conditions. Many acres were "cut off" ("dressed"), particularly those that had not been ploughed up in the usual manner, by the end of January. Heavy rain in February and early March then stopped all operations and ploughing down and cutting off were delayed until many yards had at least 3 feet of new growth before cutting was completed. The very wet conditions of the previous picking season, coupled with a complete absence of frost during the winter, left the land in an unworkable condition, and it was almost impossible to obtain good tilths anywhere.

A prolonged period of drought and cold easterly winds followed cutting off and growth was very slow during the spring and early summer. The drought was broken in early June, but the continued low temperatures delayed growth and by the end of June many yards had not reached the top wire.

In July a warm wet spell of weather gave new impetus to growth and a great deal of bine was made in a short time. Unfortunately, this caused the burr to be produced over a long period, with the result that the crop ripened very unevenly. At the end of August (27th-28th) a cold south-easterly gale caused considerable damage throughout the region. This, coupled with a lack of sunshine, produced a crop that was generally poor in rub and aroma with a lower yield than was previously expected. This lack of condition was accentuated on the picking machine due to the toughness of the stem and the extra force needed to remove the hop from the bine.

Irrigation during the early drought period was tried by a number of growers, but the results were irregular and in some cases no increase in crop was observed.

### Pests and Diseases

The overshadowing event in 1957 was the confirmation of Progressive *Verticillium* Wilt in a yard on Rosemaund Experimental

Husbandry Farm, Preston Wynne. This was the first known case in the West Midlands and all possible precautions were taken to contain the outbreak to this one area on the farm. The whole yard (10 acres) was completely destroyed and as a consequence, the very extensive experiment on the comparison of the hops in sward and arable has been lost.

No other outbreak in the region has so far been found and every precaution to prevent any possible spread from this source is being taken.

Throughout the West Midland region the chemical stripping of the lower leaves in place of the usual hand method was used on a considerable acreage. No damage to the hop has occurred so far, but upward drift of the material in some yards caused the death of leaves above the banding string. This should be avoided, otherwise serious accidents can occur when spraying is delayed to a later date than normal. It is also possible that too much material running down the bine could cause damage to the cuttings if these are needed for propagation purposes.

The heavy aphis attack was effectively controlled by systemic insecticides. The "knock-down" effect now usually incorporated in these materials was very helpful in the early sprays when growth was so extremely slow. Some build-up at the end of the season in places emphasized the continued need for thorough control by the "small hop" stage.

Downy Mildew spikes were extremely numerous in the early part of the season. The low temperatures and effective removal of the basal and lateral spikes, coupled with routine spraying, enabled the crop to be gathered without any serious damage from this source.

Powdery Mildew was again troublesome, particularly on Northern Brewer. "Karathane" was used quite effectively as an eradicant but is of little use as a preventative: it should be used as a supplement to the normal sulphur sprays. Early application of sulphur still appears to give the most satisfactory results.

Nettlehead (Virus) did not appear to have spread more rapidly than usual but it continues to take a heavy toll in the many affected yards throughout the region. Experiments to control the spread of this virus by eliminating as many insect pests as possible from the hops have so far given very contradictory results. Time of application is probably of paramount importance and more knowledge concerning the life cycle of possible vectors will improve the present arbitrary method of application of once a month.

Hop Picking

At the commencement of picking heavy rains in the northern part of the region brought flooding in the Teme Valley. It was not serious enough to damage the crop but prevented many areas from being picked for at least a week and then only under very difficult conditions.

The number of hop picking machines in use continues to increase and it is estimated that nearly 80 per cent. of the acreage grown in the West Midlands was machine picked. In view of the very high annual quota many growers were inclined to include a large amount of extraneous matter in their samples. This has rebounded on the average valuation, which was lower than for several years past.

An interesting experiment by a grower has been the sulphuring of the whole crop as soon as it was picked, in a special chamber apart from the kilns. The results appear to have been very satisfactory.

The replacement of the "green sack" by rigid containers, in which the hops could be handled and preserved in better conditions, would make this type of sulphuring a simple operation.

# APPENDIX VII

## THE 1957 HOP SEASON: SOUTH-EASTERN REGION

CATHERINE L. JARY

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The 1957 season was one of contrasts in weather conditions. A mild winter with virtually no frost left the ground working very badly in the spring, especially after the heavy traffic of tractors carting bines for machine picking. The hops came into growth early and many gardens had made considerable bine growth before dressing. The dry spring with persistent strong winds, followed by the hot early summer, caused severe drought conditions and there was heavy mortality among newly-planted setts which were not watered. Even mature hop gardens on the poorer soils suffered obviously from drought and those growers who had installed irrigation equipment could not have chosen a better year. In early July, however, the weather broke, and continued mainly cold and wet for the rest of the season. Under these conditions the hops, even without irrigation, recovered to a remarkable degree and produced some very big cones and much heavier crops than appeared possible earlier in the year. The late season and lack of sunshine, however, prevented full resin development and tended to make the hops weigh light. These factors were also accentuated by too early picking in some cases.

On June 29th severe hailstorms occurred in a narrow belt extending south-west from Sittingbourne across Kent and East Sussex, and caused substantial damage to hops on 30-40 farms. For many of these farms it was the third or fourth successive year of hail damage.

Irrigation was introduced on several farms, mainly by low-level sprinklers. The effect on newly-planted hops was spectacular in the conditions of exceptional drought and heat; it enabled them not merely to survive, but to grow substantial crops. Yields of 12 cwt./acre from bedded setts and 8 cwt./acre from cut setts were reported. It should be pointed out, however, that these were not experiments in which performance under irrigation could be compared with controls under otherwise similar conditions. Moreover, the stocks concerned were disease-free clones, which are normally capable of

giving similar yields in the year of planting under reasonable weather conditions. The effect of irrigation on mature hops was less easy to assess.

### Pests, Diseases and Physiological Disorders

The death of mature hills in the winter, sometimes before dressing and sometimes after, appears to be increasing. To some extent this can be explained by the increasing acreage of Whitbread Golding Variety, which is more susceptible to Downy Mildew in the rootstock than the old established Fuggle which it is replacing in the wilt area. In some cases, however, Fuggle itself has been affected. The cold spring winds caused a number of cases of the "Ivy Leaf" form of leaf distortion, particularly among Goldings in the exposed area of East Kent, but the plants grew out of it with the warmer weather. Bramling Cross showed a stunting of the early bines, which remained quite short while growth was taken over by later bines.

It was a bad year for the spread of *Verticillium* wilt and Nettlehead. It is quite probable that many of the new outbreaks could be attributed to the spread of infected material by the gale of July, 1956. Unfortunately the method of spread of Nettlehead is still not established. The year was remarkable for the almost complete absence of Downy Mildew after the first spikes in the spring. This was probably accounted for by the long drought period which prevented the production of summer spores, and the relatively low temperatures in July and August when there was plenty of moisture. The weather conditions favoured Mould (Powdery Mildew) which was particularly noticeable on Northern Brewer. Aphis attack was very heavy, but systemic insecticides have provided the complete answer for growers against this pest. It is, however, becoming necessary to increase the number of spray applications from two to three to give protection through the whole season; with soil treatment in many cases the single application to the crown of the hill is no longer sufficient.

### Varieties

The acreage of new varieties continues to increase. In the south-east most of these are wilt-tolerants which now account for 8 per cent. of the total acreage in that region, but Northern Brewer and Bullion (wilt sensitives) are also increasing. The growers' demand for wilt-tolerants is still far from satisfied. Clean stocks of the three new

East Malling seedlings (D1; D3; J2) and of Bramling Cross and three wilt-tolerant males are now in the hands of specialist propagators in the eastern counties, and small quantities of setts should be available to growers in the winter of 1960-1 after which supplies should increase fairly quickly.

### Picking and Drying

There were about 170 hop-picking machines operating in the south-east for the 1957 harvest and these picked between one-quarter and one-third of the total acreage. The growers' concern to fulfil their quota induced some to put in a lot of rubbish and bad samples were heavily penalized in valuation. On the other hand, some very good samples were produced.

There was widespread interest in improving drying techniques and equipment. Two new types of drier, the two-tier kiln and the continuous belt drier, were installed and attracted many visitors. The two-tier system can be introduced into existing square kilns of suitable dimensions and is therefore a more practicable proposition than the continuous belt drier which requires a large new building. Both systems naturally had teething troubles but these would seem to be capable of solution.

# APPENDIX VIII

## NOTES ON RECENT PUBLICATIONS AND DEVELOPMENTS IN HOP RESEARCH

F. C. Thompson

### (A) England

#### Publications by Staff of the Department of Hop Research, Wye College

F. H. Beard (with Miss C. L. Jary). "New Varieties. Summary of the present position." *Annual Booklet for 1957, Association of Growers of the New Varieties of Hops*, p. 5.

F. H. Beard. "Downy Mildew and the new varieties of hops". *Ibid.*, p. 26.

E. Q. Laws and H. S. Darling. "Treatment of hops with dimefox." *Nature*, 1958, **181**, 498.

H. S. Darling. "Systemic insecticides and the ratio of green to dried hops." *Nature*, Vol. 181, p. 1811.

R. A. Neve. "Sex chromosomes in the hop *Humulus lupulus*." *Nature*, 1958, **181**, 1084.

F. C. Thompson. "The effect of spacing and height of wirework on the pattern of growth, yield and resin production of hops." *J. Inst. Brew.*, 1957, **63**, 399.

#### Research at Other Centres in England

East Malling Research Station

Research on *Verticillium* wilt disease of hops, and on hop virus diseases, is carried out in the Plant Pathology Department at East Malling and during the past year publications by members of staff there have included:

R. V. Harris. "Progress in research on *Verticillium* wilt and virus diseases in hops in 1957." *Rep. E. Malling Res. Sta. for 1957*, p. 161.

A review of items of special interest to hop growers.

G. W. F. Sewell and J. F. Wilson. "Weed hosts of the 'progressive' hop strain of *Verticillium albo-atrum*." *Ibid.*, p. 126.

Some common hop garden weeds have been shown to be susceptible to infection by the "progressive" hop strain of *V. albo-atrum*. Problems arising from this discovery are discussed but it is stated that the danger of spread of the "progressive" strain in wild plant communities should not be exaggerated.

J. T. Legg and P. J. Ormerod. "The nickel content of hop plants with reference to Nettlehead symptoms." *Ibid.*, p. 129.

There is evidence that Nettlehead infected plants have a relatively high nickel content but this appears to be a symptom, rather than a cause, of the disease.

P. W. Talboys. "The possible significance of toxic metabolites of *Verticillium albo-atrum* in the development of hop wilt symptoms. *Trans. British Mycological Society*, 1957, **40**, 415.

## Brewing Industry Research Foundation

The investigation of the chemistry of the resins and other constituents of the hop continues at the B.I.R.F. and a number of papers have been published in the past year. A valuable and up-to-date account of this work was given by Dr. G. A. Howard of the B.I.R.F. staff, in the Annual Report of the Department of Hop Research for 1956, p. 81. The emphasis of present research is on a study of hop oil, the composition of which has been shown to be influenced by variety.

The importance to growers of this work should be stressed since, though changes in brewing practice are slow to take place, it is apparent that the trend is towards using hops on the basis of chemical analysis, and, eventually, the assessment of the brewing value of hops will be made on this basis.

## National Institute of Agricultural Engineering

In collaboration with the Department of Hop Research at Wye, staff of the Mechanical Engineering Department of the N.I.A.E. are now undertaking a series of investigations on hop drying. The first paper giving details of the results of these investigations has now been published by P. H. Bailey, who is in charge of the work, and the author's summary of this paper is given below.

P. H. Bailey. "Hop drying investigations I. The performance of conventional 20 ft. square kilns with forced draught." *J. Agric. Eng. Res.*, 1957, **3**, 35.

Changing methods in the hop harvest are leading to a reconsideration of hop drying installations. As a starting point for investigations into hop drying, the performances of two single-deck 20 ft. square kilns were measured in the 1956 and 1957 seasons. With a drying air quantity of 54,000 lb./hr. (velocity ~ 35 ft./min.), the loadings used were 3,000-5,000 lb. of wet hops and the specific evaporation ranged from 42 to 53 lb. of water per gallon gas oil according to the size of the loading. No differences were evident between the drying rates with machine-picked Wye variety hops and hand-picked Fuggles after adjustment for the size of loading. It was found that Burgess's formula for the determination of drying time requires modification to give satisfactory results with 20 ft. square kilns.

Some other publications of interest relating to hop investigations in England include:

J. R. Hudson. "Further observations on the heavy metal content of hop plants in relation to Nettlehead." *J. Inst. Brew.*, 1957, **63**, 488.

The observation made in the 1955 season that foliage from hop plants which were suffering from Nettlehead contained higher contents of various heavy metals than did leaves from healthy plants, has received substantial confirmation from results obtained with hops of the 1956 season.

Institute of Brewing Hops Advisory Committee. "Institute of Brewing hop trials: 1955 crop." *Ibid.*, 1957, **63**, 312.

Taking into consideration all the trials made with these hops, it may be concluded that the majority of brewers taking part would be quite willing to substitute at least 25 per cent. of their normal hop grist by D1 and D3 in proportion to their alpha-soft resin content. J2 appears to be a milder hop readily acceptable at 25 per cent. replacement and, in the majority of cases at 50 per cent. on a weight for weight basis as its alpha-soft resin content is very similar to that of Fuggles. OT48 (Bramling Cross) has an American aroma, but is considered suitable by most brewers, at least at 25 per cent. replacement. V94 (Sunshine) appears to have a characteristic pleasant flavour which is acceptable to some brewers at 25 per cent. replacement, but has been acceptable on one occasion only out of

three trials at 50 per cent. Therefore, it may not be as suitable as the other four experimental hops to act as a Fuggles replacement.

A. H. Burgess. "Soil requirements of some of the new varieties." *Annual Booklet for 1957, Association of Growers of the New Varieties of Hops*, p. 12.

Bullion and Bramling Cross appear to do well on most soils, and thrive on the heavier and wetter soils favoured by the Fuggle variety. Northern Brewer and Pride of Kent have a preference for "Fuggle land" and do not thrive on lighter soils. In contrast Whitbread's Golding Variety does not do so well on the heavier soils.

B. S. Furneaux. "Soils for hop growing." *Wigan Richardson & Co., Hop Report 1957 Season*, p. 8.

This paper stresses the need for a deep, well drained soil for satisfactory hop growth.

The writer emphasizes the large demand for water as the hop plant reaches maturity and states that irrigation is not the complete answer since, where it is practised, hops on shallow soils, receiving all the water they need, are still very disappointing.

## (B) Research in other Countries

### Germany and Czechoslovakia

From reports in the literature, and from personal contacts, it is evident that hop research in Europe continues to expand and that, particularly in Germany and Czechoslovakia, considerable attention is being paid to machine picking. Contact between Wye staff and European workers is maintained through the medium of the Scientific Commission of the European Hops Culture Committee, and it is apparent that, in general, hop research in England continues to be in advance of that elsewhere (and, in fact, advice on hop problems is frequently sought from this country by foreign workers).

Advances in hop drying in Germany, however, have had some influence on developments in this country in recent years and the following literature references have been noted in the past year:

Anon. "Multipurpose drying plant for hops." *Brauwelt*, 1957, **97**, 1314.

A note on a plant for drying grain or hops.

R. Fischer. "Hop drying and its technical prerequisites". *Hopfen Rundschau*, 1958, 9, 95.

A collection of papers on various aspects of hop research carried out in Czechoslovakia has recently been published.

Czechoslovak Academy of Agricultural Sciences. "Hop growing research in Czechoslovakia." Prague, 1958, pp. 200.

The work described covers the improvement of the Czech (Saaz) hop varieties; the effect of different times of dressing, on hop yield; the effect of cutting the bine at harvest (as with machine picking) on the build-up of carbohydrate reserves in the rootstock; studies on a hop virus disease termed the "curling disease" or "Kräuselkrankheit" and its relation to plant and soil mineral nutrient contents; tests of various fungicides and insecticides for the control of Downy Mildew and hop aphis respectively; studies on hop resins and tannins.

The report shows that hop research is being actively pursued in Czechoslovakia and many of the investigations are on similar lines to those being pursued in England. It is of interest to note that, under Czech conditions, autumn dressing gives a better yield than late spring dressing, but that early spring dressing gives the highest yield, which agrees precisely with the results of a trial at the Rosemaund Experimental Farm in Hereford. The work on mineral nutrition in relation to "Kräuselkrankheit" is allied to similar investigations on the Nettlehead virus disease in England, and it is of interest that Professor E. S. Salmon, when visiting Czechoslovakia some thirty-five years ago, noted that the "Kräusel" disease of hops appeared to be very similar to Nettlehead. Improvement of the Saaz hops is being carried out by a mass selection technique, choosing the best hop plants from the various hop-growing districts in Czechoslovakia and propagating material from these plants for distribution to growers.

## France

R. Marocke. "Some observations on hop soils and on hop manuring in Lower Alsace." *Bull. de l'Assoc. Française pour l'Étude du Sol*, 1957, No. 93, 1045.

In this paper the author approaches the problem of hop manuring, in the Alsace region of France, along similar lines to those developed at Wye. After stating that manurial requirements can

never be precisely defined for hops in general, since they depend on the nature of the soil, climatic conditions and the variety grown, he proceeds to outline a manurial scheme for hops of the varieties Spalt and Strisselspalt grown in Alsace.

His manurial scheme, for soils in a good state of fertility, is, per acre, 100-140 lb. N, 80 lb. $P_2O_5$ and 150 lb. $K_2O$; this in addition to a dressing of dung. Where analysis shows the soil to be deficient in available nutrients, appropriate adjustments should be made in manuring.

It is of interest that the author does not recommend heavy applications of phosphatic fertilizers where the soil is well supplied with phosphate.

F. Gouin. "The therapeutic uses of the hop." *Brasserie*, 1957, No. 133, 201.

A historical review of the medicinal uses of the hop and an account of attempts, in recent years, to use hop resin components as antibiotics, in particular for the treatment of tuberculosis.

An intensive investigation of this aspect of hop usage was carried out in the U.S.A. in the period 1946-1954 with largely negative results—see J. C. Lewis *et al. Wallerstein Laboratory Commun.*, 1955, **18**, 33.

Belgium

F. Hoed, P. Elsocht and J. Hoed. "Activities of the Belgian National Hop Institute during 1957." *Petit J. du Brasseur*, 1958, **66**, 191.

Investigations carried out by the Institute include manurial and cultural trials, tests of different fungicides and insecticides and a full programme of variety trials. In the latter, certain of the Wye varieties continue to do well, particularly Northern Brewer.

A picking machine has been bought and used for harvesting trial plots.

U.S.A.

W. A. Crocker. "Experimental control of two-spotted mite on hop vines with acaricides." *Wallerstein Laboratory Commun.*, 1957, **20**, 141.

Experiments with various acaricides, for the control of red spider in hops, are described. The most effective was found to be D.M.C.—di (*p*-chlorophenol) methylcarbinol.

AUSTRALIA

A conference organized by the Australian Section of the Institute of Brewing, and held in Tasmania in March, 1957, was largely concerned with hops and included the following paper on plant breeding:

A. S. NASH. "Production of new varieties of hops in Victoria (Australia)." *Proceedings of the 4th Convention, Institute of Brewing (Australian Section)*, 1957, p. 17.

As the result of breeding experiments a new variety, Ringwood Special, has been raised. This combines high yield and resin content with good aroma and has the advantage that it matures 7-10 days earlier than the Californian Cluster hop grown in Victoria.

Polyploidy, and X-ray treatment of seeds for the production of mutants, are techniques which are being used in the breeding programme.

NEW ZEALAND

H. O. ASKEW and R. J. MONK. "Physical and chemical changes during development of the hop cone." *Rep. Cawthron Institute for 1955-1956*, p. 40.

This article gives the results of experiments designed to study physical and chemical changes from early burring to maturity. From the flowering stage the content of reducing sugars is built-up until cone formation takes place and then decreases as the cones approach maturity. Resins content, in contrast, increases from burr to cone maturity.

H. O. ASKEW and R. J. MONK. "Experiments on drying of hops." *Ibid.*, p. 42.

Hops were dried under conditions similar to those used in conventional drying in England (i.e. temperature not exceeding 150° F.). The authors' conclusions are "These experiments have shown that the rate of loss of water, and the variations in the moisture contents of the cones during drying follow somewhat the same patterns as those found in the experimental work on the flue-curing of tobacco leaves. On the other hand, probably due to the more intense drying of hops, especially when a constant relatively high temperature is used, the enzyme systems concerned in the respiratory processes, which are the final causes of loss of dry matter in the treatment of tobacco leaves, cease to function very early and thus there is practically no loss of dry matter during processing of hop cones." The authors also state that little or no loss of total soft resins occurred during drying, in their experiments.

H. O. Askew and Joyce Watson. "Molybdenum deficiency in hops." *Ibid.*, p. 45.

Cases of poor growth in hops in which the leaves show an incurling accompanied by a brown speckling which later turns white, have been found to be associated with a low molybdenum content and to respond to applications of molybdenum.

T. Christie. "A note on an outbreak of *Verticillium* wilt in a Nelson hop garden." *N.Z.J. Sci. Tech.* (Sect. A), 1956, **38**, 15.

T. Christie. "Pathogenicity tests with species of *Verticillium*." *Ibid.* (Sect. A), 1956, **38**, 17.

These two papers refer to an outbreak of a wilt disease caused by *Verticillium albo-atrum*, in a New Zealand hop garden.

Tests on the *Verticillium* isolates indicated that the fungus was of a more virulent type than that described in England as the "fluctuating" strain. The outbreak of the disease occurred in part of a young garden where hops had been planted after potatoes. This part of the garden was grubbed and sown to grass; no further evidence of *Verticillium* infection was found, subsequently, in the remainder of the garden.

T. Christie. "Black root rot (*Phytophthora cactorum*) of the hop plant." *Ibid.* (Sect. A), 1956, **38**, 277.

This disease particularly affects the Californian variety of hops grown in New Zealand. No methods of chemical control have, so far, proved effective and the only treatments which can be suggested are to improve soil drainage and adopt rigorous plant hygiene measures.

Other varieties, such as Fuggle, grown in New Zealand, are largely resistant to the disease in the field.

It is of interest to note that this disease is of no economic importance in England except in the Wye variety, Brewer's Gold.

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